MANUAL

OF

PLANT DISEASES

BY

PROF. DR. PAUL SORAUER

Third Edition—Prof. Dr. Sorauer

In Collaboration with

Prof. Dr. G. Lindau *And* Dr. L. Reh

Private Docent at the University of Berlin

Assistant in the Museum of Natural History in Hamburg

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Volume I

NON-PARASITIC DISEASES

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BERLIN

WITH 208 ILLUSTRATIONS IN THE TEXT

ERRATA.

Contents, page X, line 23, *for* Leguminaceae, *read* Leguminosae.

Page 8, line 23, *for* stems, *read* shoots.

" 23, " 16, " preventive, *read* preventative.

" 53, " 5, " Prunualus, *read* Prunulus.

" 93, Fig. 4, caption, *for* Schömünzach, *read* Schönmünzach.

" 99, line 34, *for Mucor spinosa, read Mucor spinosus.*

" 167, " 22, " Arahanose, *read* Arabinose.

" 204, " 37, " Fusiarium, *read* Fusarium.

" 232, " 5, " Leguminoseae, *read* Leguminosae.

" 21, " Dioscora, *read* Dioscorea.

" 265, " 19, " Zolites, *read* Zeolites.

" 273, " 6, " *B. substilis, read B. subtilis.*

" 7-8, " *Clostridium gelatinosa, read Clostridium gelatinosum.*

" 18, *after* Mold fungi, *insert (Mucor stolonifera* and *Aspergillis niger).*

" 293, " 20, *for* homogany, *read* homogamy.

" 338, " 30, " fruit spears, *read* fruit spurs.

" 339, " 11, " Fruchtuchen, *read* Fruchtkuchen.

" 420-22 " Leguminaceae, *read* Leguminosae.

" 430, line 11, *after* inner growth, *insert* (internal intumescences).

" 442, Fig. 80, caption, *for Acacia pendulata, read Acacia pendula.*

" 461, line 24, *after* rough places, *insert* (scurvy spots).

" 498, " 1, *for* Chapter XL, *read* Chapter XI.

" 548, " 24, " psycho-clinic, *read* psychro-clinic.

" 696, " 22, " *Bacillus pseudarabinus, read Bact. pseudarabinum.*

" 723, " 38, " Grapholithia, *read* Grapholitha.

" 765, " 36, " Boulle céleste, *read* Bouillie céleste.

" 802, Fig. 186, caption, *for* formaton, *read* formation.

" 855, line 11, *for* Trula, *read* Torula.

" 11, " vernatis, *read* vernalis.

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PREFACE TO THE GERMAN EDITION.

For the third edition of my manual I have requested the assistance of Professor Dr. Lindau and Dr. Reh. In the second volume of the work, the former has treated of vegetable parasites and in the third volume the latter, the animal enemies of plants.

Such help seemed necessary because, since the appearance of the second edition, the published results of investigations have been so numerous that too long a time would have been required for mastering the material. Otherwise when the last sheets appeared the first would have become obsolete. Even with this division of the work, this unfortunate condition has not been entirely overcome and an attempt has been made to obviate the difficulty by listing some of the more important recent material in a supplementary bibliography. If the absence of some works, especially of the earlier literature, is noted the explanation lies in the fact that we have emphasized especially those studies necessary for the support of our presentation of the subject. A more detailed bibliography would be possible only if the individual diseases were treated in monographs.

I kept for my own work the revision of the first volume, comprising the non-parasitic diseases. The fact that this volume is the most extensive is explained by my standpoint, already sufficiently characterized in the preface to the second edition,—because I lay the chief weight on a knowledge of the diseases produced by atmospheric, soil and cultural conditions. The disturbances caused by these factors are not only the most abundant and permanent but also often form the starting point for parasitic diseases.

On this account, supported by my own studies and the observations of other investigators, I was especially anxious to show how the same plant species could be changed structurally and in habits of growth according to position and the constitution of the soil. Individuals are sometimes more disposed to a definite form of disease or are more resistant to it, according to the difference in their constitutions.

This holds good also for their behavior towards parasitic organisms. It is thus evident that not only must the latter be combatted by directly destructive methods but also the chief emphasis should be laid on the possible constitutional change of the host plant. Therefore, we will find the most essential task to be the breeding of resistant varieties. At the time the first edition of this work was published, the undersigned stood alone as representative of this theory of predisposition to parasitic attack, but now many of the most prominent investigators are counted among its supporters.

And thus I hope that the idea for which I have fought since the beginning of my scientific activity, that is, the formation of a *rational plant*

hygiene, will finally come to full recognition. Primarily, we must learn to protect the organism from disease, and then, through force of necessity, may take steps to heal an organism which is already diseased.

In the first volume, the first section of the introduction treats of the nature of disease, while the second takes up the history of its investigation. It should be understood by the term "historical" that I did not wish to write a history of phytopathology, which would have taken much more thorough preliminary study, but did consider it desirable to attempt to sketch the process of the development of this branch of knowledge, in order to show how the present point of view had developed in the course of time.

In looking through the specialized part, the reader may also find that even in the present edition conclusions once based on a considerable number of my own investigations have been abandoned. The aid of illustrations, so absolutely necessary in phytopathology, has been made use of to an appreciably larger extent in describing diseases. In accordance with the character of the book, new anatomical drawings especially have been added. In the volume on parasitic diseases many tables have been gathered together for the sake of comparison, in order to make clear to the reader the different genera of one family in their distinctive characteristics.

The new drawings were made by Fräulein H. Detmann and Fräulein E. Lütke, whom I thank very much for their work.

Most of all, however, I wish to thank my collaborators. With me, they had to solve the difficult problem of presenting the material in a space determined by contract *before* the revision. During the revision, we found ourselves confronted by the question either of giving to the whole subject a briefer form than was originally intended, or of working up some chapters in detail while summarizing others. We chose the latter course and treated the seemingly most important sections thoroughly and the groups, which had been sufficiently worked over in other books, in a correspondingly limited way.

Schöneberg, October, 1908.

PAUL SORAUER.

INTRODUCTION.

Section I.

THE NATURE OF DISEASE.

1. Limitation of the Conception of Disease.

Our first task is evidently the necessity for defining the province of which we will treat and for expounding what we understand by the term "Disease."

If we call "sick" only those cases in which the organism undergoes such a disturbance in its functions that its existence seems threatened, we will be in a dilemma when we consider the changing developmental forms of our cultivated plants, for we will then discover that the above explanation is insufficient. We know, for example, that our species of cabbage, kohlrabi and cauliflower are descended from a plant similar to bank-cress which, in its natural development as a wild plant, shows no tendency toward the formation of large leaf-buds such as cabbage heads, nor of root-like swellings of the stem, as kohlrabi. These vegetables have been produced by selection and cultivation and are characterized by a condition which we term *parenchymatosis,* because the woody elements have been replaced by a tender parenchyma, due to the high degree of nitrogen continuously supplied from generation to generation. In dry, hot summers young plants grown on soils poor in food materials begin to show a marked ripening and, in connection with this, a reddish blue tone in their leaves. In case kohlrabi, under such conditions, makes any development worth mentioning, it becomes "stringy," that is, its flesh is traversed by tough, hard fibres, making it "woody." Investigation shows that the kohlrabi plant by the curtailment of the supply of water and food materials is well on the way toward again developing a wood-ring with prosenchymatic elements, as found constantly in the wild plant. Very similar conditions are found in carrots in which our normal uncultivated plant possesses a solid woody root, rich in starch. Our cultivated varieties, on the contrary, have become thick, fleshy structures; the best containing no starch at all but the greatest possible amount of sugar. Only in the so-called fodder varieties, as, for example, the white giant carrot, is still shown an abundance of starch. Hoffmann-Giessen has experimentally developed our cultivated carrot back to the wild form.

Now, is the cultivated form a diseased condition since it actually succumbs more easily to certain disturbing influences, or is the reversion of the

cultivated plant to the normal wild one to be considered a disease? In any case this reversion is a condition which must be combatted as it is evidently unfitted for our cultural efforts.

In considering such examples we see that, in treating questions of disease, we shall have to follow two lines of work. We must naturally first keep the organism's aim in sight. And this aim, which the organism derives from its very origin, is to live, and in fact to live as long as possible. Everything which has once been originated persists as the effect of the causes leading to its production, until a stronger factor arises which disturbs the fixed order and brings about other groupings of material, form and function (an inseparable trinity). But, up to the time of interference of such a factor, the developed individual, with the sum total of the forces inherent in its substance, maintains its then existing order, that is, its individuality, to which a generally definable age limit is set. This necessary mechanical defense of its individuality against the constant attacks of external factors may be termed the "force of self-preservation." In following the second line, the aim of cultivation, developed from the relation of the plants to human needs, is an added important factor. These conditions of the vegetable organism opposing our cultural endeavors will be combatted as inexpedient. But such conditions need in no way threaten the existence of the individual and therefore, according to the above explanation, are not diseases. Yet they belong to the province of the pathologist as disturbances which must be considered and overcome.

In limiting the conception of disease, we meet with similar difficulties in double blossoms, in as much as this doubleness is due to the fact that the stamens have been changed into petals and in doing this have deformed the pistil. This leads to sterility. The length of life of the individual plant is not injured in any way by this sterility, but, on the contrary, is actually lengthened as, for example, in double petunias. But the aim of the species is affected since such double blossoms are no longer able to produce seeds. If this kind of doubling becomes general, such species must die out in case all vegetative reproductive organs are missing. This variation in structural development, threatening the existence of the species, however, is directly sought for in cultivation and any reversion to the normal, seedbearing form is selected out. Here indeed the aim of cultivation contradicts the natural aim and pathology tries hard to overcome the natural trend opposed to the momentary direction of the cultivation, although in doing this, it directly threatens the existence of the species.

Such antagonisms are very numerous. In the list of cases in which only individual organs become diseased, one such local disturbance can influence injuriously the organism as a whole, but can yet be useful to the individual. We would call attention here to the dropping of young fruit due to drought. The cultural aim is naturally interfered with but the economy of the tree reaps the benefit in as much as it saves the reserve materials, which would have been used in maturing the fruit. As a result of this, the

tree is not only in a position to develop the next set of leaves, but also to set numerous fruit buds, which would have remained suppressed had a full crop exhausted the store. When late frosts injure the blossoms and young fruit, the individual organs are certainly severely sickened and fall off later; but the tree itself has the advantage of saving a quantity of food material. As often happens, the cultural purpose can also profit in this case, because the blossoms developing after the action of the frost yield more perfect fruit and thus an increased revenue.

This defines clearly the difference between pure and applied science. Pure science studies the process of disease in itself and can be only cellular pathology, while applied science takes into consideration the effect on the diseased individual and its agricultural significance. We must unite both forms of science since we take the purely scientific studies as the basis of our consideration and explanation of the economic effects of the attack of sickness.

The consideration of the cultural needs forces us to the following division of our subject; first of all, we will have to consider all cases which threaten the individual aim of the organism, i. e. its longest possible life;—these are *absolute diseases*. Then we must discuss the disturbances which the momentary *cultural aim* experiences and which we term *relative diseases*. These relative diseases may vary since what cultivation considers worth striving for to-day may be neglected to-morrow. For example, with savoy, every reversion of the plant to Brussels sprouts is a disturbance of the cultural aim to be avoided by changing the seed. If we intend growing Brussels sprouts, however, each variation of these plants toward the savoy form is a deterioration, undesirable in cultivation. Finally, malformations are usually unimportant agriculturally but must be considered. Such malformations may be a maturing of organs in a manner differing from the usual process of development. These natural occurrences, which, we believe, may often be traced back to changes in pressure conditions and other mechanical influences due to the formation of the organs, constitute a special branch of knowledge,—*Teratology*. This is, however, to be considered as one branch of pathology and we will have to draw into our discussion these phenomena so far as their causes are known or may be surmised with some certainty.

The method of treating the material which falls under the province of the study of plant diseases or *Phytopathology*, will have to be according to the following scheme:—

I. *Pathography* or *symptomatics*, i. e., the description of the disease according to its individual signs or symptoms.

II. *Pathogeny* or *etiology*, namely, investigation as to the cause of the disease. Only after the causes are known is it possible to bring into use

III. *Therapy* or the *study of healing* methods and to draw into the discussion

IV. *Prophylaxis* or some *method of prevention*.

2. The Production of the Disease.

If we have said that we must begin with the individual cells when judging a disease, we must know first of all how complicated an organism the cell is and how its structure and function depend on the constitution, position and action of the micellae composing it.

Let us, for example, examine some effects of "swelling." The cell wall at a given time is saturated to a definite degree with water of imbibition, that is, the cellulose micellae held together by cohesion are provided with a water sheath with a certain amount of distention. The micellae will be separated further from one another or will approach one another more closely as the water supply varies; that is, the walls will sometimes become more dense, sometimes more flaccid. Such fluctuations are brought about in the protoplasm of the cell by the action of substances which withdraw water osmotically. Similar processes are observed in chloroplastids, for example, in grain leaves if acted upon by weak chlorin fumes or by sulfuretted hydrogen. The chloroplasts are seen to shrivel with the use of chlorine while the chlorophyll *grains* become pale green, doughy, almost gelatinous bodies with sulfuretted hydrogen.

In the cell wall, marked phenomena of flaccidity may often be restricted to single spots. The so-called *"bead-cells"* in winter grain may be taken as examples of this. Individual cell groups near the larger vascular bundles show bead-like convex centres of flaccidity on the inner side of their walls, which later lose their cellulose character. If young, vigorously growing potato stems are exposed to frost, different groups of leaf parenchyma cells will be found later whose walls seem swollen in lines to four times their normal thickness. In this may be observed the browning and decay of the more dense wall lamellae into stripes which lie imbedded in a homogeneous, lighter parenchyma.

In the case of very flaccid membranes, however, molecules will be able to penetrate the greatly enlarged micellar interstices, which cannot force an entrance through the smaller ones, because of their size. If changes in the constitution of the protoplasm have been caused by frost, we find substances passing in and out which could not have been transferred before by the plasma body. The red coloring matter and the sugar in frosted red sugar beets (Beta) pass easily from the parenchyma of the beet into the surrounding water. This would be impossible in the cut beet, if it had not been frosted previously. The loosening of the structure of the organic substance is a very normal process the intensity of which depends on the action of external factors, such as water supply, light, warmth, etc. If these normal processes exceed a certain limit, they lead to disturbances which so alter the structure and function of the cells that they become unable to maintain life. Every other process of cell life may be similarly affected. Under the influence of different factors of growth, the process may be hastened or retarded. We know that each life function oscillates between wide limits, according to

the action of each individual vegetative factor. We call these limits the ***minimum*** and ***maximum*** and the degree of functioning at which a life process most favors the development of the organism the ***optimum.***

The field of oscillation of the functions about the optimum, ***within the limits promoting development*** may be called the ***"latitude of health."*** This should not be confused with ***"the latitude of life,"*** for the organism can still live outside the latitude of health, but its functions are so weakened that its development undergoes arrest or retrogression and this condition is ***disease.*** If this cessation of the function is temporary, the condition falls under the conception of ***"check"*** and we speak of check from cold or from darkness, etc. But we must guard against the belief that the appearance of sickness or a condition of check or of death in any species is connected with any precise numerical values for the separate factors of growth. If, for example, we take two cuttings from the same plant and cultivate them for some time in sand sterilized by heat with the same quantity of food materials but keep one cutting in a hot house and the other out of doors, in the end the two will show a very different susceptibility to frost and other atmospheric factors. The specimen grown in the hot house freezes more easily; that is, its minimum for the maintaining of life is raised. Temperatures, at which the specimen grown in the open air remains within the latitude of health, arrest the life processes of the hot house specimen. Experiments to determine the maximum and minimum of other factors of growth show very similar variations so that we may ***arrive at the conclusion that for each habitat each plant has its own scale of needs, its own optimum, maximum and minimum and therefore possesses its own specific latitude of health.***

Further, the circumstance that the different functions are lost at different times should be considered. If, for example, potato tubers are left for some time at a temperature of about —1°C., it will be found that respiration ceases sooner than the conversion of starch into sugar. This results in an accumulation of sugar in the tuber which is called "turning sweet of the potato." If the temperature is raised more slowly to possibly +10°C. the stored sugar disappears through the increased activity of the protoplasm and respiration. If cucumbers, tobacco and other heat loving plants have to withstand a temperature of +5° to 8°C. for some time, they show a yellow-leaf condition, which disappears with continued increase of heat. The plants do not die, but assimilation and growth are so suppressed that processes, such as the formation of gums, may be introduced, leading to the premature death of the individual. As in the preceding case of deficient heat, deficiency in food materials or light,—in short, every decrease of any vegetative function,—so retards the normal direction of the functions that the interaction of these for the purpose of a beneficial metabolism is misdirected. Other combinations and functional directions (for example, fermentations) are now produced, which initiate the ending of life prematurely. The same effect will necessarily appear every time the maximum of any vegetative factor is exceeded, or even approximated.

In very many cases a sickness which has already set in is indicated by chlorosis, beginning inconspicuously and progressing slowly. Even if it is possible to observe the very beginning of chlorosis, the beginning of the sickness itself has in no way been discovered since the first molecular changes, which have led to the yellowing of the chloroplast, still remain unknown to us. The boundary line where any single factor of growth ceases to be beneficial and becomes a retarding factor may indeed be determined experimentally but in this we see only the final result and not the course of development; i. e., the processes initiating this final result. So far as our powers of observation are able to discover, *health and disease represent conditions which imperceptibly pass over into one another.*

3. The Relation of the Plant to its Environment.

In the attempt, undertaken in the previous section, to demonstrate how health and disease present interdependent conditions like the links of a chain, we kept in view first of all the so-called *constitutional diseases*. By this are understood the disturbances in nutrition which influence the whole organism sympathetically and are the results of deficiency or excess of one of the necessary vegetative factors. *Local diseases* due to accidental interference must be opposed to these *general diseases*. In them the organism as a whole in its full reactionary capacity is exposed primarily to a disturbance affecting only one individual organ. While the action of the necessary inorganic factors of growth come under consideration in constitutional diseases, in local diseases the important influences are those mutually exerted on one another by the organisms.

There are insects which seek out the plants in order to satisfy their needs for nutrition or for habitation, or the plants themselves mutually influence one another. We find as the most pertinent example the influence of street trees on the plants growing on the other side of the hedge row. We notice especially in times of drought that the grain and potato plants found within reach of the tree's shadow are not only weaker in development but wilt sooner and to a greater degree than the other plants in the same field. This disadvantage is due chiefly to the tree which keeps off the rain and its roots which withdraw the soil water. In the field itself we frequently find different places in which the seed has grown very poorly because the wind grass has choked the grain. The seed was not sown too thin but the germination and first development were choked by cold and deficiency in oxygen because of impervious spots in the field. In spring the soil does not dry so quickly in these places and the moisture is retained longer; the soil consequently warms up less easily and suffers for need of oxygen. The wind grass *(Apera spica venti)* which occurs everywhere in grain fields is less sensitive and under such conditions develops more quickly than grain. Because of its greater size, it chokes out the seedling grain. Similar conditions arise in connection with other weeds, which, developing more rapidly, not only take food materials out of the soil and away from the cultivated

plants, but also injure them by shading. Actually, however, this *struggle for room* is the factor first manifested in each plant community and makes itself felt in all field and forest plantations. In the grain field and in every forest tract, the *individual first growing most strongly* chokes out its weaker neighbors. It is the universal question of the *strong driving back the weak* which must find expression in all community life.

The kind of community life just described in its relation to spacial separation can be termed *neighborhood* in distinction from the mutual influencing of organisms when united in space. A relationship of this latter kind *(symbiosis)* must be the more intimate since one organism lives with the other. De Bary (1866) distinguished a *mutualistic* symbiosis from an *antagonistic*, according to whether the influence is mutually beneficial or detrimental. The terms chosen by Vuillemin (1889) for this relationship *"symbiosis"* and *"antibiosis"* seem less fortunate to us. We find examples of a mutualistic community also termed *commensalism* by van Beneden in 1878, as companionship at table, in the little bunches of roots of the sago palm (Cycadeae) which occur on the surface of the soil, rigidly branching like witches' brooms and which harbor numerous chains of Nostoc in the large holes in their bark. The genus Gunnera shows similar conditions. Further, the case is often mentioned in literature, in which a water plant, *Azolla caroliniana*, resembling our *Salvinia natans*, in the axillary hollows of the leaves, gives shelter to another Nostoc with longish members (Anabaena). The most accessible example of mutualism is offered by the structure of the lichen body, in which fungus and alga remain connected permanently, to their mutual benefit,—*Lichenism*.

In the same way may be explained the symbiosis of certain mycelia and the roots of Fagus, Corylus, Castanea and some conifers, the so-called root fungus or *mycorrhiza* which is usually considered a necessary and universal arrangement. In connection with the mycorrhiza should be mentioned the protective device called *Bacteriorhiza* by Hiltner[1] and Störmer (in Beta and Pisum). Bacteria penetrate from the soil into the outer cell layers of the roots, actually causing a browning of these layers, but otherwise not especially disturbing the health of the plant. According to Hiltner, however, these bacteria prevent the penetration of other injurious organisms (Phoma, etc.).

Finally we will consider the arrangement of root tubercles, which may be found in different forms and grouping on the roots of the Leguminoseae and form those well-known grape-like bodies in alders, which not infrequently may be observed as spherical nests of short branched roots as large as one's fist. The organisms in the tubercles making the nitrogen of the air available for the plant and described by the students of legumes as *Rhizobium Leguminosarum* Frank, or *Bacillus radicicola* Beijerinck, are bacteria

[1] Hiltner and Peters. Untersuchungen über die Keimlingskrankheiten der Zucker- und Runkelrüben. Arbeiten d. Biolog. Abt. am Kais. Gesundheitsamte. Vol. IV. Part 3. 1904.

just as the producers of the silver white tubercles in *Isopyrum biternatum* which, according to MacDougal[1] develop extensively in soils free from nitrates. On the other hand, the recent investigations of Björkenheim[2] seem to prove that a fungus is concerned in alders.

In antagonistic symbiosis, de Bary has used the expression *saprophytism* and Johow in 1889 defined the idea more closely by distinguishing *holo-saprophytes* (those lacking chlorophyll) from *hemisaprophytes* (those containing chlorophyll).

Bischoff has contrasted with this the conception of *parasitism*. According to Sarauw[3] the expression "parasite" was brought into use in 1729 by Micheli for the Balanophoreae[4]. In agreement with the classification of the saprophytes, Sarauw has distinguished *holoparasites* (those without chlorophyll) from *hemiparasites* (those provided with chlorophyll).

Saprophytism is the ability of an organism to take its nourishment from decomposing organic substances, while the parasite draws nourishment from the living organism. If we test this classification, based on the forms of nutrition, we find that here, as in all branches of science, a sharp systematic subdivision is assumed only by representatives of a young school, while those of the older and more experienced school are convinced that transition forms exist between the different groups.

If relative adjacency be compared with *nutrient association* (symbiosis) each forest and each grain field shows how constantly one organism influences the other, according to whether the one leaves any food materials, water and light, for the other. Just as spacial separation sets no fixed limitation to the form of nutrition, the sub-division of the organisms into those with purely mineral nutrition and those dependent on organic substances should be abolished.

Although plants suited for independent self-nourishment can draw their nutrient material from purely mineral substrata, yet the process actually present consists in their taking humus substances which furnish the food materials in an easily absorbable form because of the activity of a rich bacterial flora in the soil. The advantages of supplying our fields with animal manures should be thought of in this connection.

Modern views have strongly modified this distinction between saprophytism and parasitism, since they have brought forward numerous examples showing that the organisms called obligate parasites may become dependent on saprophytic nutrition in definite developmental phases and conversely that saprophytes in many instances can assume the parasitic mode of feeding. Miyoshi's[5] investigations give us a clear insight into the way

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[1] Minnesota Botanical Studies 1894.

[2] Björkenheim, Beiträge zur Kenntnis des Pilzes in den Wurzelanschwellungen von *Alnus incana*. Zeitschr. f. Pflkr. 1904. p. 129.

[3] Sarauw, G. F. L., Rodsymbiose og Mykorrlizer saerlig hos Skovträerne. Botanisk Tidsskrift 1893. Parts 3 and 4.

[4] But Tournefort in Mém. Ac. Paris 1705, p. 332, speaks of plants which grow on other plants.

[5] Miyoshi, Manaba, Ueber Chemotropismus der Pilze. Bot. Zeit. LII, 1894, pp. 1-27.

in which such a change takes place in nutrition. The experiments undertaken at Pfeffer's Institute in Leipsic show that fungus hyphae are irritable chemically and that the direction of their growth may be influenced either towards the stimulating substance, *(positive chemotropism)* or away from it *(negative chemotropism)*. Indeed their mode of growth also can be changed since, for example, a tendency towards sprout formation sets in with a higher concentration of the solution. The commonest mold species, which occasionally become parasitic (Mucor, Penicillium, Aspergillus) show an irritability with substances which almost always can be presupposed to be characteristic of phanerogamic plants. Besides dextrin and the neutral phosphoric acid salts, sugar especially attracts fungi, in case the concentration is not too high. Thus, for example, grape sugar in a 50 per cent. solution acts repellently for *Mucor stolonifer,* the active agent of decay of fruits. Acids, on the contrary, and alkalis from the beginning act repellingly. The germination tubes of the summer spores of *Uredo linearis,* a grain rust, are attracted by a decoction of plum and wheat leaves. Especially interesting are the cultural results with *Penicillium glaucum,* whose hyphae bore through the cell walls of a leaf impregnated with a 2 per cent. cane sugar solution. In the same way they penetrated artificial cellulose membranes and the epidermis of bulb scales which lay on a nutrient gelatine.

These are especially important clues capable of explaining the numerous case of sickness from Penicillium. It is well known that this mold, the most abundant agent of decay in stone fruits, first begins to spread when the ripening process has converted the starch into sugar.

In connection with the penetration of Penicillium into the scales of bulbs, we find abundant examples in the cases of decay in the tulip, hyacinth and lily bulbs which occasionally lead to lawsuits. This decay occurs especially extensively when wet years prevent the maturing of the bulbs or if the bulbs are stored when containing an unusual amount of sugar and then used prematurely for forcing.

Thus we see how the cell contents and the cell walls of the host plant can determine the penetration of hyphae and the transition of the saprophyte into a parasite.

4. Parasitic Diseases.

Supported by various carefully studied cases of parasitism, many observers so generalized the conception of parasitic diseases that they assumed them to be present wherever organisms are found gathered together. In many cases this is supported by experiments in which the parasitically living organisms were injected into the host and were able to produce a local disease in the tissue.

With this method the apparent proofs of parasitic disease were accumulated in such a way that one was forced to the assumption that there could be scarcely any disease which was not caused parasitically. Infection ex-

periments in the laboratory led gradually to the knowledge that in many cases of disease *no specific* parasites were present but universally distributed fungous and bacterial forms. The further the studies advanced, the more cases were listed in which inoculation with spores of the most common molds, as Botrytis, Penicillium, Cladosporium etc., also the most widely distributed soil bacteria, *Bacillus subtilis* and *B. vulgatus,* develop disease in healthy tissue. And finally was recognized the importance of the question how organisms universally present could at times be parasitic in their mode of life and, at other times, saprophytic. Corollary to this question is one which was deduced from rapidly increasing discoveries in many experiments with the same methods of infection; certain varieties or even individuals were resistant while others succumbed easily to the parasitic attack. What is the cause of such differences?

Some of the investigators brought forward the theory of virulence as an explanation of such cases. It was emphasized that in each separate case parasitism as a struggle between two organisms had depended necessarily upon which was the stronger. If the weapon of attack of the parasite, for instance, be an enzyme, able to dissolve the cell walls of the host, then it would be explicable that this process would take place more quickly in proportion to the increase of solvent ferment formed in any given unit of time. Since it was now possible to prove experimentally that the strength of the attack varied in cultures of different nutritive substances, it could be said that, where it became the active agent of disease and its production of enzymes especially abundant, it must have been especially virulent. Bacterial cultures furnished the greatest number of examples of change in virulence. Yet such cases were also determined with fungi. De Bary's statement concerning the frequently encountered mold, *Botrytis cinerea,* is well-known. He states that the mycelium must develop by the customary saprophytic form of nutrition up to a certain strength before it becomes parasitic and successfully attacks the living parts of the plants. I succeeded in getting like results with the conidia of this fungus. Masses of spores were strewn on delicate Begonia leaves and kept very damp. After several days it was possible to observe that, where these spores had lain in thick masses, the leaf had become diseased, showing a browning of the tissue. Where the spores had lain isolated, however, no attack could be discerned. The action of the quantity of ferment excreted by the individual spores therefore proved insufficient, while the excretion from a mass of spores brought about infection. It can thus easily be understood that parasites, like every other organism, develop most strongly when the nutritive conditions are most favorable and that the stronger and the more abundant the formation of their vegetative organs, the greater the excretion of the enzyme and accordingly the increase in strength of their attack. Therefore their virulence is raised.

But these processes are not sufficient to explain the fact that in one field when a number of varieties are grown in a single plantation, certain ones may be completely destroyed while others standing next are but little injured.

or perhaps absolutely unattacked. Since in such cases the parasite is quickly and extensively distributed on one variety and not on the other, although the atmospheric conditions and other factors of vegetation are equally favorable, the specific constitution of the host plant in these two cases must have determined whether it would become diseased. Thus we arrive at the conclusion that for the production of a parasitic disease the *presence of the parasite alone is not determinative* but the constitution of the host organism is also a determining factor.

The many infection experiments have led to a classification of the living creatures infesting other organisms and capable of attacking the tissue, in which one group is described as *obligate parasites* when able to attack the host plant in all stages of its normal development. Of this group there have been separated as *wound parasites* all such organisms as cannot attack the organism possessing normal protective devices but need the changes in tissue offered by the surface of a wound. In a great many instances, however, we have recognized the fact that the parasite only finds the environment required for its development when the host has been affected and its functions weakened. Such conditions will appear here as were also decisive in the experiments carried on by Miyoshi (see preceding section). This group bears the name *"parasites of weakness."*

To this last group especially belong the numerous species which during many generations live on dead organic substances. They therefore must be spoken of as saprophytes which occasionally become parasitic,—*facultative parasites*. Therefore the boundary between parasitism and saprophytism is lost here and even in those species which are always parasites *(obligates)*, such as the varieties of smut, we find developmental phases with a saprophytic mode of nutrition.

If we now, however, study more closely the families of our closest parasites among the fungi, namely, the smuts and rusts, we will find one fact brought into prominence by the most recent investigations and repeatedly substantiated; namely, that *the energy of growth of the parasite depends on the host plant.* We have examples proving that the same fungus occurs in different species of the same host genus in the same habitat, sometimes growing luxuriantly in many large centres, sometimes sparsely in small forms, according to whether the one species has fleshy leaves and the other thin ones. Indeed, the *rusts* are so dependent upon their host plants that *biologic races* are formed which, agreeing formally, nevertheless show differences in adjusting themselves to definite host plants and either cannot develop at all, even when carefully injected upon a related host plant, or develop only slightly. Thus we have a special form of the common black rust of grains on rye, another on wheat, another on oats etc. Mycologists cherish the conviction that this development into individual races through the accommodation to a special host plant is a widespread phenomenon constantly increasing. What else can such a race formation indicate than that parasites in their demands have been and still will be *most closely connected with the*

constitution of their substratum? If, however, as previously shown, the closest parasite is thus very dependent upon its host plant, it only goes to show how completely it agrees with non-parasitic plants in its demands for *very definite* nutritive conditions, and that with a change in these the parasite changes its character and either adjusts itself or disappears. Stahl's observations[1] on myxomycete plasmodia show that we must take these phenomena of adjustment into consideration. If the water in the culture glass was replaced by a ½ per cent. grape sugar solution, the plasmodia either died from this sudden change or shunned the sugar solution. Gradually, however, they accepted it, having accustomed themselves to a more concentrated solution (perhaps by a certain loss in water) and indeed in such a way, that, replaced in pure water, they showed considerable injury.

In regard to the formation of races, Pfeffer[2] expresses himself thus; "Present discoveries . . . make it clear that the tropistic reaction of the same species of bacteria, flagellates etc. gradually changes in accord with the existing cultural conditions. Thus it should be understood that in the same species in nature and in artificial cultures there is found at times a very appreciable ability to respond to reactions and changes, varying to a disappearing point, according to a definite stimulus. Indeed after wide experience it seems possible to breed races in which a definite reaction to tropism has been partially or entirely lost."

Parasitism is nothing extraordinary. Possibly it is not a factor which has newly appeared since plant cultivation was begun. It should be considered as a nutritive form which arose gradually with the development of organic life and a necessary one, to be looked upon as the last link in the chain formed by the mutual interaction of organisms. This last link begins with those organisms which have the ability of forming organic substances from inorganic material through the action of light. Joined to these are the plants with the lesser need of light, such as are found among the bacteria living in humus where an addition of quickly decomposible organic substances presents essential aid to the nutritive process. As the struggle for light gains in importance with an increasing number of organisms, the more pertinent becomes the development of groups of organisms requiring but little light and an ever greater need of a method of nutrition by which the raw material is offered in the form of organic, easily re-worked substances. Such conditions are found at present in saprophytism.

With the struggle for light in the case of a constantly increasing number of individuals comes also the struggle for space. In the course of time the lack of space will lead finally to those forms of adjustment in the plant world which require soil for their habitat only in the beginning, if at all, and have chosen some other organism as a centre of colonization. The mutual interrelations forming under such conditions are partly friendly, partly hostile, just as they occur in mutualistic and in antagonistic symbiosis.

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1 Stahl in Bot. Z. 1884, pp. 163-66.
2 Pfeffer, Pflanzenphysiologie, 2 Edition. Vol. II, p. 763. Leipzig 1904.

Among the species of plants using some other organism as a habitat, we find the formation of very different devices for the means of nutrition. Beginning with lichens, the assistance given by thalli acquires greater and greater significance, up to the formation of a mycelium. The mycelium is satisfied with dead bark, or rather that attacked when dying, or with the leaf substance of its host, or it can only eke out its existence when, with the help of the enzyme which it excretes, it attacks the living organic substance and then calls parasitism into existence.

But in all these relations the one fundamental law becomes evident that each organism is associated with the *definite constitution of its substratum.* This substratum must have the exact requirements for satisfying all the demands of the organism, otherwise it cannot thrive. Therefore all the organisms which we call parasites make very definite demands on some host. How narrowly limited these demands may often be is shown directly by the bacteria, for which at times slight fluctuations in the amount of heat, the acidity of the nutritive mixture etc., lead to the replacing of certain species by others better adjusted.

In order to cite only a few new examples we will mention the investigations of Thomas Milburn[1] who cultivated fungi as well as bacteria. Of the former he found in the case of *Hypocrea rufa* that an increase of osmotic pressure first suppresses the formation of pigment in the conidia and finally inhibits the formation of conidia. In this fungus the color of the conidia changes with the reaction of the medium. If the reaction is acid, green spores are formed; if alkaline, yellow spores. A well nourished mycelium forms no fruit in the dark but does develop conidia when poorly nourished. The yellow color of the mycelium of *Aspergillus niger* is very sensitive to light and when exposed to it turns black within a few hours. The *Bacillus ruber balticus* found on potatoes, the so-called "Kieler bacillus"[2] which, according to Laurent, forms acids on certain nutritive soils and alkalis on others, is so influenced in its production of coloring matter by the nutritive substratum that it develops a violet color on an acid substratum and orange red on an alkaline substratum.

Lepeschkin[3] observed that the strictly aerobic bacteria from the sputum in pneumonia, *Bacillus Berestnewi,* can develop a branching growth on strongly alkaline and on strongly acid substrata, but gradually acidifies the alkaline substratum. In the presence of sugar (dextrose) a pinkish color appears together with the disintegration of the little rods into oidia. In the presence of larger amounts of nitrogen compounds (aspargin, lecithin, peptone) the whole mass of bacteria turns yellow. The optimum for growth lies probably at 25°C. Even at 35°C. the bacterium grows very slowly and at 38°C. is no longer able to grow. It is killed at 55°C.

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[1] Thomas Milburn, Ueber Aenderungen der Farben bei Pilzen und Bakterien. Centralbl. f .Bakteriologie usw. II. Division 1904. Vol. XIII. Nos. 9-11.

[2] See Breunig, Untersuchungen des Trinkwassers der Stadt Kiel, 1888.

[3] Lepeschkin. Zur Kenntnis der Erblichkeit bei den einzelnen Organismen usw. Centrabl. f. Bakteriologie usw. II. Division. 1904. Vol. XII. Nos. 22-24.

If dependence on the constitution of the nutritive substrata may be proved for parasites, naturally the strongest agent in combatting them is the removal of the favorable nutritive substratum and its alteration into one unfavorable for the special parasite.

Since cultivated plants, by the fact of their division into susceptible and resistent varieties, demonstrate that there is a possibility of altering the nutritive substratum produced by living plants, *the production of such resistent individuals through cultivation* is the first aim of our work, in regard to overcoming parasitic diseases. It is more effective than the present method of fighting parasites locally or preventing their attacks, a method which was deduced from a narrow point of view. At most this may be carried through effectively for small centres of disease but for mechanical reasons is impracticable for general use. From this point of view parasitism is not such a great menace as it has been represented to be.

If parasitism is a definite nutritive form of certain groups of organisms which has become necessary in the natural development of the living being, it must have its stage of equilibrium in the sphere of nature. Arrangements must exist which counterbalance parasitism. It must be possible to hinder its effectiveness by factors simultaneously effective, for otherwise the nutritive organisms could no longer exist. This counterbalance is found in the very definite, often narrowly restricted environment which determines the existence of the parasite. That condition of a living creature which we are accustomed to term "healthy," without being able as yet to define it, is one such restricting limit which the parasite under normal conditions is not able to overcome. For, since the defenders of the extreme theory have represented such parasitic micro-organisms as dangerous which are constantly present everywhere saprophytically and as yet have not killed the host plants as a whole, these plants must thus possess some *protective devices* in their normal development, which are repeated in the same sense from generation to generation. We constantly find occurring as such, unbroken deposits of wax and cork, definite acidity of the cell content etc.

That we now find more and more adherents to our theory is proved by the statements of one of our most important students of parasitism, Metschnikoff[1] of the Pasteur Institute. After giving a number of examples to show that the production of the parasitic disease is conditioned by *two* causes, first, the parasite and secondly, susceptibility of the organisms, he says, (page 7) "if these internal conditions are powerless to arrest the development of the excitor of a disease, the disease is produced. If, however, the organism firmly resists the development of the bacteria, it is protected and thus proves itself immune." (Page 6) "One can no longer be of the opinion that, every time an excitor of disease penetrates a susceptible organism, the presence of the same inevitably calls forth this specific diseased condition. Löffler's discovery of the diphtheria Bacillus in the pharynx

[1] Immunität bei Infektionskrankheiten by Elias Metschnikoff, Professor of the Pasteur Institute in Paris. Authorized Translation by Dr. Julius Meyer. Jena, Gustav Fischer, 1902.

of healthy children has been repeatedly substantiated since that time and yet it is impossible to doubt the etiological significance of this bacillus for diphtheria. On the other hand it has been proved that Koch's Vibrio, although the real incitor of Asiatic cholera, nevertheless, occurs in the digestive system of healthy people."

The healthy organism thus possesses a natural immunity and any disturbance of this aids the possible parasitic attack.

5. Epidemics.

If we can define *endemics* as a local malady, whose production is connected with definite conditions, narrowly limited locally, then *epidemic* may be called a community malady. The expression "malady" indicates the multiplicity of the diseased individuals in contrast to isolated cases of disease. Epidemic thus describes that condition in which numerous individuals succumb to a given form of disease, developing over large territories.

If an epidemic breaks out, conditions must be present which disturb the functions of the organism in numerous individuals so strongly that their lives are either threatened with a premature end or are finally brought to this end. This disturbance arises from external causes. If these causes are parasitic organisms, their existence, as was shown in the preceding chapter, is dependent on the factors of growth favorable to their extensive increase. Among these factors belongs the breaking down of the immunity of the nutritive organism.

Even with the assumption that a parasite not indigenous to the countries which suffer from the disease might have caused the epidemic by its incursion, this circumstance in no way changes the fact that the *factors of growth already existing are determinative for the production of the epidemic.* For, whatever may wander into the country, be it animal, fungus or bacterium, this incursion would not produce an epidemic, if the newcomer found no opportunity for great increase and wide distribution. For example, who does not remember very effective representations of the importation of the Colorado beetle as the destroyer of our potato crop, or the extensive introduction of the San José scale as the destroyer of our fruit trees? Initiated persons know how often embargo regulations and compulsory disinfection have advanced protection against the importation of parasitic fungi ("White Rot of the Grape" etc.) and they have partially succeeded in getting it.

Experience has taught that no theoretically imagined but practically impossible complete destruction or quarantine of such parasites has possibly protected us from epidemics but the circumstance that they did not find the necessary climate and soil for their increase. Conversely, the Phylloxera plague should be remembered which, despite all human endeavor and the spending of many millions, became more and more widespread. The Phylloxera finds, even in Europe, sufficiently favorable conditions for existence and on this account defies such means for fighting it as embargo, disinfection, processes of extermination etc. Upon consideration, it becomes

gradually clearer that small living creatures, in fact, the smallest which are introduced by means of articles of commerce or can be easily distributed by dust and wind, may be kept out of small enclosed places but not away from extensive open localities, and that one proceeds better by presupposing the possibilities of a widespread distribution of such organisms although real danger is to be recognized only if an easy capacity for its increase has been proved. If now in all parasitic incursions, not the presence of the parasite but the conditions favoring its spread are proved decisive for the production of the epidemic, then a change in these conditions is the best means for combatting them.

In regard to measures for its suppression and prevention, however, the epidemic furnishes special pointers in that, when it occurs over extensive areas, it excludes as causes all the factors which vary from one another in the different diseased districts. For, since the malady attacks large plantations despite the variations in such factors as, for instance, situation, composition of the soil, agricultural methods etc., these factors cannot be the cause. Rather the cause should be sought in those influences which are the same throughout the whole country. Actually, this can only be the climate. On the other hand, in endemic diseases, conditions of the soil usually act decisively. They are to be considered either direct causes of disease since, through unfavorable chemical or physical peculiarities they permanently disturb the functions of the plants, or they act indirectly, favoring the increase of the parasites and the strength of their attacks. In this, as a rule, they suppress at the same time the growth energy of the host plant. Soil dampness is the condition most favoring this. When the capacity of thick, heavy soils for retaining water is very great on the level or in hollows, an accumulation usually occurs which finds no outlet and produces a deficiency of oxygen, with an excess of carbon dioxid. The plants indicate this functional disturbance by a change in the chlorophyll apparatus. The leaves, gradually turning yellow, form a suitable growing medium for certain groups of fungi.

In all endemics and epidemics a simultaneous sickening of a great number of individuals *indicates a considerable period of preparation leading up to the actual outbreak of the malady.*

For, according to our conception of all the phenomena of life as dynamic processes, each case of disease may be characterized as the immediate or indirect result of mechanical disturbances exercised by the separate factors of growth on the composition and function of the substance. The life of a cell is a constant struggle between the oscillatory forms momentarily present in the unstable organic compounds and the disturbances constantly exercised upon them by the factors of growth.

A change in the substance and with it one in its function appear at once if the disturbance in one factor of growth is so strong that it is able to change the form of oscillation existing up to that time. So long as the disturbances as a whole have the effect of contributing to the development of the organism as a whole, that is, the vegetable individual, the plant remains

within the latitude of health. Disease follows if the cell or the cell complex is so changed that ultimately the whole structure suffers.

Now, however, the fact, always confirmable by examples, that certain cultivated varieties show a tendency to disease not shown by others under similar conditions of growth, furnishes us proof that in the different individuals the organic substance may oppose a differing amount of resistance to the same attacks. This would mean that more attacks are necessary for one individual than for another in order to carry it out of the latitude of health. If, in an epidemic, only large numbers of individuals always suddenly become sick, besides the especially susceptible ones there must also be others among them for which a greater number of attacks and therefore a longer period of action is necessary, in order that they may become sick. Therefore a longer period of the influences producing the disease must have led up to the outbreak of the epidemic and these influences are to be seen in the atmospheric factors.

Therefore, according to our theory, each epidemic is, so to speak, the explosion of a charge which had been slowly accumulating for some time. Its cause therefore is not to be sought, at least exclusively, in the existing factors of growth present at the moment but in the accumulation of attacks which for some time previously have been effective in the same way. In parasitic epidemics the extensive occurrence of the micro-organism in no way represents the first stage of the phenomenon but is a final effect of long preparation. This preparation consists on the one hand in the gradual production of life conditions favorable for the enormous increase of the micro-organisms, on the other hand, in the gradual weakening of some functions of the host which we believe are always connected with this and a correlative increase of other functions.

If, for example, we study the best known fungous epidemic, potato blight, observation shows that a period of warm, dull, sultry days usually precedes the outbreak. The fungus *Phytophthora infestans* is always present. Its astonishingly rapid increase, however, takes place out of doors only if abundant atmospheric precipitation and a warm motionless air continuously favor the production and the scattering of the swarm spores. During weather of this kind the potato plant develops a greater amount of sugar, a more rapid stem growth and a great number of young leaves; that is, it produces an especially susceptible environment for the development of the fungus which scorns organs that have become old. In this way we find that whole fields may become diseased in a few days.

On the other hand we do not find the Pytophthora epidemic if the same amount of precipitation occurs in the same space of time but in cold weather. The epidemic cannot develop if, with increased warmth and a clouded sky, persistent strong winds keep blowing. A similar relation is shown in rust epidemics of grains. Like the majority of fungi the grain rusts love continuous moisture. Yet by no means do we always have rust epidemics in wet years, although there might be scarcely one grain field in which the rusts

would not be present every year. The epidemic develops at the time when the leaves are young and only during periods of warm days with frequent even if almost unappreciable showers which make possible a longer retention of moisture among the plants. Cold, wet summers generally prevent the development of rust epidemics. Similar conditions may be observed in bacterial epidemics.

Therefore, epidemics are forms of disease which mature only because of far reaching factors. Only certain weather combinations of longer duration may be considered as the initial cause. Naturally the intensity of the epidemic will vary locally because local factors will produce special favorable conditions. In this way is explained the occurrence of centres in which the malady appears first and disappears last, in case not all the individuals are killed in a short time. In this way is explained further the retrogression of epidemics into endemics; that is, into narrowly confined centres of disease. Among the epidemics produced by animal parasites, those caused by grain flies are the most abundant with us. They usually take place during periods of continued warm, dry weather after the winter conditions have been favorable for the individual grain flies which in some regions are always present. So far as statistics now go, preferred centres and points of departure may often be determined for this plague-like distribution. Thus, for example, the province Posen is proved to be especially favorable soil for grain flies. From Posen as a centre an epidemic usually radiates towards Brandenburg, Pomerania and West Prussia. The whole Eastern part of Germany suffers more from injuries due to flies than does the Western part. North Western Europe is usually visited more frequently and intensely than South Western and South Eastern Europe.

According to the point of view here developed any treatment of the epidemics by fighting the symptoms as they appear must offer the least prospect of success, because these are only the result of initial stages which existed long before. If the parasites are present in enormous quantities the desire to kill the micro-organisms is seen to be a vain one since no insecticide or fungicide can even approximately reach the main mass and still less cause its death. Thus as the pestilences are induced by general factors acting universally, they must be combatted by broad means which undo the life conditions of the parasite and change the constitution of the host, that is, the functional direction. If, for example, long wet periods permit the bacterial rot of potato, which we call *"wet rot,"* to appear in epidemic proportions, any other means than increased ventilation of the soil can scarcely be used successfully. So far as specific anaerobic bacteria are concerned, the factor favorable to growth (lack of oxygen with excess of carbon dioxid) is removed by an increase of oxygen and also by the decrease for them, as well as for other bacteria, of the condition fundamental to their abundant increase, an abundance of water. Nature generally works in this way. If, after the rainy periods, dry, windy weather continues for some time so that the soil dries and the air circulates freely, the progress of the disease comes

naturally to a standstill. The recommendation of every regulation for the prevention of infection by the removal of infected potatoes from the field, or by deep subsoil cultivation, or the burning of diseased straw in grain epidemics, we consider to be a work with insignificant results as contrasted with the effect of changed life conditions for the parasite. The amount of infected material in extensive districts does not come under consideration at all. At times in the case of damp rot, soil bacteria co-operate and form a dense condition of the soil. If atmospheric influences make themselves so felt in certain soils that certain bacterial groups are able to attack potatoes or other fruits of the field, the number of the causative agents of the disease originally present is almost of no significance.

The last named examples of parasitic epidemics due to such microorganisms as may be assumed to be constantly present in the soil or the air, make clear to us, however, how little prospect of success is offered for combatting an epidemic once it has broken out. A greater protection for our cultivated plants lies in *preventive methods.* Such a preventive process in epidemics, aside from the formation of an universal plant hygiene, can, however, be induced by the drawing up of a *chart of pestilences;* that is, a summary of plague centres for each individual epidemic. In the correspondence of certain characteristics for a number of plague centres, single factors are especially distinguished as fundamental for the production of an epidemic; for example, dryness in light soils is shown to be favorable for fly epidemics of grain or for the heart-rot of sugar beets etc. Having thus determined weather and soil combinations dangerous for each individual epidemic one can make one's attack prophylactically by means of cultural regulations as soon as the threatening combination of conditions continues for some time. Direct means which kill the parasites, such as sprinkling with copper sulfate or dusting with sulfur, will then act only as hinderances to the epidemics if used preventively.

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6. Artificial Immunization and Internal Therapy.

It is quite natural that in phytopathology the same course of ideas has developed as in animal pathology and accordingly it is not strange that there has gradually become evident a theory of immunizing plants artificially; i. e., of so changing their bodily composition that the parasites will no longer find the nutritive soil necessary for colonization, for their wider distribution.

There already exist several works along this line in which, following in part *serum therapy,* use is made of immunifying substances obtained from the parasite itself, and again where mineral salts are used. Along the former line belong Beauverie's[1] investigations with *Botrytis cinerea* and those of Ray[2] with very different kinds of parasites. The latter obtained

[1] Beauverie, J., Essai d'immunisation des végetaux contre les maladies cryptogamiques. Compt. rend. Paris 1901. II, p. 107.
[2] Ray, J., Cultures et formes attenuées des maladies cryptogamiques. Compt. rend. Paris 1901. II, p. 307.

the result that parasitic organisms may be influenced in artificial cultures by the nutritive medium used. In this their virulence is proved always to be less than it is under natural conditions. By leeching the cultures, fluids may be obtained which may be used for the immunization of the host plants against the organism concerned. The author concludes further that the infected plants are actually cultures of the parasites concerned. In this maceration and extraction of the diseased plant parts must furnish fluids which would exercise an effect similar to that of the parasite itself. When modified by increased temperature, these fluids can be used for immunization.

E. Marchal[1] should be especially mentioned as a representative of the other line of immunization experiments. He worked with mineral substances, some of which were nutritive, while others should be considered poisonous. He sowed lettuce in Sachs' nutrient solution with the addition of substances which kill fungi. The young seedlings, after the development of the first two or three leaves, were infected with the zoo-conidia of *Bremia Lactucae* and then kept in a moist atmosphere. The plants, not rendered immune by the substances in the nutrient solution which would kill fungi, were at once attacked. Of the salts used, the addition of from three to four ten-thousandths copper sulfate to the nutrient solution was clearly proved to increase the resistance. The addition of 1-10000 copper sulfate no longer showed any immunizing effect whatever. Manganese sulfate acted less completely; ferrous sulfate had no effect at all. Calcium salts also (up to 2-100) could increase the resistance while nitrates and also, curiously enough, phosphates lessened it.

The idea of increasing each individual's susceptibility to vegetable parasites by changing the cell sap through the addition of foreign substances was also taken up by zoologists who proceeded in accordance with the discovery that parasitic animals, for instance, scale, seek out weakened plants especially.

Now, however, was associated with this the thought that universal conditions of weakness in cases of constitutional disease as well as conditions of susceptibility to parasitic attack could be healed by supplying salts of some definite kind to the plant body extra-radically. This taking up of substances otherwise than through the roots was called *"Internal Therapy"* and was developed methodically.

In 1894, I. Schewyrjov[2] published an article on "the impregnation of the wood in living trees with solutions of coloring matter" (Ueber die Durchtränkung des Holzes lebender Bäume mit Farbstofflösungen"). In it he describes the apparatus which he constructed for this purpose which we will call nutrition tube and nutrition basin. The tube is of steel, pointed at one end, which is driven into the bark, while the other end is closed by a cork, through which passes a gimlet. The tube is filled with the experimental liquid, through special openings, by means of a rubber tube. Then the gimlet

[1] Marchal, E. De l'immunisation de la laitue contre le meunier. Compt. rend. 1902. CXXXV, p. 1067.

[2] Schewyrjov Iwan, Berichtigung usw. Zeitschrift für Pflanzenkrankheiten. 1904. p. 70.

is bored slowly down into the wood to the desired depth so that the liquid but no air can penetrate into the canal thus formed by the gimlet. The author who had constructed other apparatus also mentioned Hartig's experiments which had the disadvantage of letting air penetrate into the wound. He then began experiments on the healing of chlorosis which were carried out in 1895-6 and in 1901, by garden owners in the Crimea.

Later Mokrzecki[1] published a number of successful experiments on the healing of chlorosis in fruit trees carried out according to the above method, in which he also pointed out that the scale had disappeared from the healed branches. He, as well as Schewyrjov, built great hope on this process, not only for the prevention of constitutional disturbances in nutrition but also especially for the expulsion of parasitic organisms.

My personal attitude toward this question is much cooler and I think that the effectiveness of the methods will be very limited. According to my experiments on the introduction of poisonous solutions into the trunk, the effect usually remains local but in the most successful cases radiates gradually from the point of introduction to a number of branches and to a considerable distance into the trunk. The constitution of the plant, conditioned by root nutrition, was not changed by this. I found in my experiments with oxalic acid that gum was produced on a number of cherry tree branches which later partially died. However, the production of gum did not progress further the following year and the trees, moreover, made a healthy growth. Like this poisonous solution, each nutritive mixture or healing serum remains limited within narrow boundaries and, as in the most favorable case, only temporarily exercises any beneficial influence. The physiological direction of the work of the whole plant will not be changed permanently.

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7. Predisposition.

We term "predisposition" that condition of certain individuals which renders them more easily and quickly susceptible to any cause of disease than are other individuals of the same kind.

That such cases exist is proved by daily discoveries as to the quantitative growth of cultivated plants. These discoveries have already found expression in the common use of the terms tender and hardy varieties and individuals which have been made less resistant. Observations show that not only different cultural varieties of the same species but even single individuals of the same variety possess a varying power of resistance to weather extremes, as, for example, cold and heat, or to parasitic attack. In the latter connection, it suffices to mention that practical workers as well as scientific investigators have now set themselves the task of breeding more resistant varieties.

At present we are only in a position to indicate the direction in which a greater individual inclination to succumb to any parasitic attack may be pro-

[1] Mokrzecki, S. A. Ueber die innere Therapie der Pflanzen. Zeitschr. f. Pflanzenkrankheiten. 1903. p. 257.

duced. In the previous divisions we have considered investigations showing that different groups of substances produced in the plant cells, as, for instance, sugar, act attractively for certain fungi in definite concentrations and repellantly in others. The number of these groups of substances is determined by very different factors, as will be shown more thoroughly in the next chapter. This metabolism will be found favorable for the nutrition of the parasite or unsuitable for it, according to the quantity produced.

In order to cite at least one example in this connection, we will refer to the investigation of Viala and Pacott[1] on the black rot of the grape. The cultures, undertaken with the fungus *Guignardia Bidwellii* which produces the disease, determined that the development of the fungus is dependent primarily on the sugar content of the nutrient substratum and its organic salts. Only young leaves were affected. They contained 1.75 per cent. tartaric acid and 4.3 per cent. glucose, while the old leaves showed only traces of these substances. The berries were susceptible from the time they began to swell and this susceptibility continued up to the beginning of the ripening stage. During this time they contained 32 to 24 per cent. of acid and 11 to 56 per cent. of sugar. During ripening the acid content falls from 9 to 2 per cent., but the sugar content increases so greatly that the fungus can no longer attack the berries. The conditions for the white rot fungus, however, are exactly reversed. By this relation is explained the strikingly different resistant capacity of different kinds of grapes. In the same way is explained the circumstance that black rot epidemics generally occur in summer after periods of cold weather with subsequent light rainfall. At this time the acid content is especially large and the formation of sugar scanty. Similar fluctuations in the concentration of the cell sap combined with the phenomena of perforation of the membrane, the varying processes of tension in the tissues and other mechanical changes also in the plants cause a state of greater susceptibility to weather extremes. The more recent investigation is endeavoring to find more macroscopic and microscopic characteristics also demarking the stages of susceptibility to injurious parasitic attacks.

The conditions pictured in the preceding example of the increased tendency of the grape to become susceptible to the black rot fungi are entirely normal developmental phases which are influenced by the weather. On this account we may speak of such states as *normal predisposition*. In contrast with these we should distinguish as *abnormal predisposition* the case in which the plant or one of its organs has fallen into a condition of weakness or of disease from other influences and in this conception of one cause of disease is first given the desired point of attack. As an example, we will call attention to the infection of leaves affected with honey dew by the black fungi, to the attacks of the so-called parasites of weakness and the migration of wood-destroying fungi from wounded surfaces.

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[1] Viala, P., et Pacottet, Sur la culture du black rot. Compt. rend. Paris 1904. Vol. CXXXVIII, p. 306.

8. Predisposition and Immunity.

In an earlier part we have pointed out that our theory as to the production of parasitic diseases has obtained support from the most renowned investigators. Metschnikoff[1], who, as professor in the Pasteur Institute for infectious diseases, may be incontestibly considered as an exact connoisseur of pathogenic micro-organisms, expresses himself as follows, "Exact bacterialogical investigations have led to the knowledge that, in the abundant bacterial flora harbored by the healthy human body, representatives of pathogenic bacterial species may also be found. Aside from the Bacillus of diphtheria and the Vibrio of cholera which so often have been proved to be *fully virulent* in perfectly healthy human beings, it has been shown that certain pathogenic micro-organisms, the Pneumococci, the Staphylococci, Streptococci and Colibacilli, are present regularly or almost constantly in the microbe flora of healthy persons.

This discovery has of necessity led to the conclusion that *besides the excitor of the disease, still a second cause of infectious diseases must exist, namely, a predisposition* or a lack of immunity. An individual which harbors one of the species of pathogenic bacteria above-named would be resistant either permanently or for the time being. But as soon as this immunity disappears, the excitor of the disease becomes uppermost and produces the specific disease."

In regard to the immunity of plants, Metschnikoff calls attention to the investigations of de Bary[2] on Botrytis, which we have already mentioned. The mycelium of this fungus penetrates the cell walls by giving off a fluid "which contains a digestive ferment and the oxalic acid necessary for this ferment. De Bary could prove the presence of this kind of toxin by the maceration of the mycelium of Sclerotinia . . . . If the resulting fluid is heated to 52°C. it can no longer digest the cellulose membrane but is still able to cause plasmolysis . . . . The results of de Bary's investigations have been confirmed and in part completed by Laurent."[3]

We have repeated Metschnikoff's words in order to characterize his way of considering the matter. The chief factor under consideration here, viz., the effectiveness of the ferment on young membranes and its ineffectiveness on older ones, gives the author reason for comparing the Botrytis diseases with the infantile diseases in human beings (measles, scarlet fever). In other cases the different processes of cork production, or suberization, found, for example, in wounds, act in a way similar to the membrane changes in the ageing of the cells. In regard to these, Metschnikoff, supported by the investigations of Massart[4], points out that the organs respond differently to the traumatic stimulus according to their age. Young leaves of Clivia, for example, re-act by forming callus, older ones simply close the

[1] Metschnikoff, Immunität bei Infectionskrankheiten. Jena, 1902, p. 6.
[2] De Bary Bot. Zeit. 1866.
[3] Laurent, Annal. de l'Institut Pasteur. Vol. XIII, p. 44.
[4] Massart, La Cicatrisation chez les plantes. Brüssel 1897.

wound by means of a deposition of cork. Further protective means are oils, resin, balsams, milky juices and gums exuding from injuries.

Metschnikoff thoroughly treats of Laurent's[1] studies which are mentioned in connection with other bacteria in the second volume of this work. At this point, however. we will emphasize especially the immunity precautions against bacterial attacks. The species of the Colibacillus, with which Laurent worked, secretes a ferment dissolving the cellulose of the potato tuber and produces also sap with alkaline reaction, the presence of which is necessary for the process of assimilation on the part of the bacteria. Now, to be sure, *Bacillus Coli communis* is naturally not a plant parasite but it can be changed into one. This happens when it is first cultivated on potatoes whose resistance has been weakened by having been dipped into alkaline solutions As a result of such cultivation the bacillus can act as a plant parasite when carried over to the same species of potato. The struggle between the Colibacillus and the potato depends therefore really on the chemical action of the alkaline secretion of the bacillus on the acid cell sap of the potato. After fertilization with potassium salts and phosphates, carrots and potatoes resist the bacillus. On the other hand, a phosphate fertilization showed in (Topinambur) that this plant then became more susceptible to the Botrytis form of *Sclerotinia Libertinia.*

Just as clearly by strong nitrogen fertilization potatoes are made less resistant to wet rot. According to our observations abundant fertilizing with nitrates, ammonia salts or stable manure, causes even the most resistant species to succumb to the potato rot. Laurent explains the difference in the action of parasites under the same method of fertilizing by the fact that with bacteria the secreted ferment can attack the cell membrane only in alkaline juices or weakly acid ones. An increased acidity of the cell sap, incited by the formation of acid salts resulting from phosphate fertilization, renders the plants immune to this fission fungus. I obtained the same results for phosphoric acid by fertilization experiments on sugar beets, in which the *Bacillus betae* was widely disseminated and had produced the bacterial formation of gum or tail rot. The rapid increase of bacteriosis with the abundant use of fertilizers which contain nitrogen might be explained in this way:—that the acid of the cell sap is thereby decreased. According to de Bary, the conditions for Sclerotinia are exactly reversed. Their ferment dissolves the cell wall only in an acid fluid. Most mycelial fungi act similarly.

If, by a change of constitution of the cell sap, sometimes a factor of immunity presents itself and, at other times, a condition predisposing to parasitic disease, we are referred by Metschnikoff (l. c. p. 39) to a further process. He cites the investigations of van Rysselberghe[2] who found, especially in the epidermal cells of Tradescantia that if these cells were

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1 Laurent, Recherches experimentales sur les maladies des plantes. Annal. de l'Inst. Pasteur. Cit. Zeitscher. f. Pflanzenkr. 1900, p. 29.

2 Osmotische Reaktion der Pflanzenzellen. Mémoires couronnés de l'Academie r. d. Belgique. Brüssel 1899.

brought into a more concentrated solution than was normal to them, they showed an increase of intra-cellular pressure. If the experiment was reversed, the pressure decreased. These changes in osmotic pressure are caused by the difference in concentration of the cell sap which may again be considered as a result of chemical changes. If the cell comes in contact with a solution too highly concentrated, it forms oxalic acid which acts strongly osmotically. With Tradescantia, van Rysselberghe proved the presence of malic acid in the normal sap and only in rare cases any traces of oxalic acid. After the plant had been kept some days in strongly concentrated cane sugar solution, oxalic acid was found in clearly appreciable amounts. The plant gradually adjusts itself to the higher concentration of this medium, producing oxalic acid in order to increase the pressure of the cell sap. The acid is supposed to be formed at the expense of grape sugar. The increased acid content will act as a protective means against bacterial attacks. It is also suggested by some investigators as a protective weapon against the attacks of snails and leaf lice.

Experiments with Tradescantia made in the opposite direction seem to me to be very significant. If tissues from this plant were taken from the highly concentrated solution and put into some strongly diluted solution, precipitates of calcium oxid crystals were observed in the cell sap, thereby initiating a decrease of osmotic pressure. When the plant was put back into a stronger solution the oxalic crystals were seen to re-dissolve and result in a new formation of acid. I found that part of the calcium oxalate crystals disappeared during the sprouting of potato tubers which also may well be ascribed to the increased formation of acid.

Pfeffer[1] also takes up this automatic regulation of the acid content since he calls attention to the frequent production of turgidity through the organic acids combined with bases. Since this remains constant during and after growth, the formation of acid must be hastened quantitatively in correspondence with the volume increase of the cell and the dilution of the cell sap thereby produced. Each unusual increase of turgor, as, for example in the effort to overcome an opposing higher concentration, will be connected with a corresponding increase in the acid production. Conversely, for example in the Crassulaceae, the decrease of the acid content has been proved with an increase in temperature and by illumination. In this same sense the experiments made by Charabot and Hébert[2] have succeeded. In the shade, the quantity of combined organic acid increases very considerably. The free volatile acids also increase. These are found in greater amounts in etiolated plants than in others. The suppression of the inflorescences increases in the leaves at the expense of the other organs.

In considering predisposition and immunity, we have brought forward the sugar content in addition to the examples of acid content. To what

[1] Pflanzenphysiologie, II Edition, Vol. I, p. 487.
[2] Charabot, Eug., et Hébert, Recherches sur l' acidité végétale. Compt. rend. hebd. 1904. CXXXVIII, 1714.

fluctuation this is exposed by changes in temperature is best seen in Fischer's[1] investigations cited by Pfeffer[2]. In the so-called starch trees, like the linden and birch, it is found that starch is formed in the bark within a few hours after the branches have been brought into a warm room from a winter temperature. In the cold, sugar is again produced from this starch. This conversion may be repeatedly produced and this kind of sugar formation seems to appear in many plants with a lowering of the temperature. If now, for any reason whatever, the sugar formed from the starch is conducted away from the organ the whole tissue may be impoverished. Pfeffer furnishes proof of this by the experiments carried out in his institution by Hansteen[3] and Puriewitsch[4]. By a continued removal of the sugar by diosmosis, it was possible to cause an ejection of starch from the isolated endosperm of grasses as well as the cotyledons of Phaseolus which had been cut off from the plant and a giving off of the glucose from the separate scales of the bulbs of *Allium Cepa.* If only a little water was present into which the sugar could pass from the organs the ejection came to a standstill because a two to three per cent. sugar solution inhibits the conversion of the starch. Therefore, either a good deal of water must be present or some other means for the removal of the starch if the ejection should be completed. Conversely, a refilling of the organs with starch could be determined if a still more concentrated solution were used.

These examples may suffice to show how in the plant body all the metabolic processes and all the resulting constructive processes succumb under constant quantitative changes which radiate in all directions from the first form of attack of the factor causing the change. Each change occurring locally is a disturbance in the condition of equilibrium existing up to that time in the molecular organization. If the disturbance is completed in one cell it must, so far as diffusible substances are concerned, be continued in the neighboring ones as are all dynamic processes.

Each place in which a new structure is formed becomes a centre of consumption. The supply of food to this new structure leads to a reduction in other parts. Each local increase in photosynthesis exerts its influence on the immediate surroundings not concerned in this process. The different factors of growth now act uninterruptedly on the plant body and disturb the momentary equilibrium, first in this direction, then in that. We have therefore a continued fluctuation in all life processes which is increased still more by the capacity for reaction peculiar to the individual, for we dare not forget that in restoring the disturbed equilibrium the organism must endeavor to increase its production of different substances. If, for example, there sets in an increase of the basic compounds conditioned by nutrition, an increased acid content will have to be brought about and conversely. And within the constant fluctuations which are a necessary result lies the condition which

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1 Fischer, A., Jahrb. f. wiss. Bot. 1891. Vol. 22.
2 Physiology I, p. 514.
3 Hansteen, Flora, 1894. Supplement.
4 Puriewitsch, Ber. d. Deutsch. bot. Ges. 1896. p. 207.

we term normal predisposition. Thus the same condition which represents a state of predisposition toward a definite cause of disease can act as a state of immunity to some other cause of disease. Proofs of this are offered by the examples above cited of the hyperacidity of the cell sap which has been shown to give immunity to certain bacterial attacks and predisposition to those of fungi. In the increased sugar content, which is connected with the influence of the acid in increasing the turgidity, we recognize a condition predisposing to injuries arising from frost and, on the other hand, a precautionary means against the disturbing action of drought.

In the very natural development of the organism, therefore, we constantly face conditions of predisposition and immunity. These are present in varying degrees in each individual since each organism has special nutritive relations and utilizes differently the same factors of growth. This explains the phenomenon that different individuals in the midst of a community of the same species become sick or conversely, in the midst of a centre of disease, remain healthy[1].

9. Inheritance of Diseases and of Predisposition.

In the last four decades further experiments have been made by many important investigators to explain theoretically the nature of heredity. In this, special consideration was given to the most juvenile condition—the embryonic plasma—as a transmitter of the capacity for inheritance and the substance which might be indicated as the chief transmitter of inheritance was sought in part in the cell nucleus.

The above-mentioned hypotheses of biologists were drawn up to explain especially the repetition of the formative processes in the successive generations of the organism. We will call attention only to Darwin's "gemmules," Haeckel's "plastidules," Weismann's "germ plasm" as an "heredity plasm," Nägeli's "idio-plasm," de Vries' "pangene," etc.

[1] The parasitic theory as generally accepted at present either still needs an explanation of these facts or is restricted to the theory of resistance. The different capacity for resistance to atmospheric extremes and other non-parasitic influences has remained unconsidered. Thus Alfred Fischer* observes "Individual variations indeed occur often enough even in man; a personal immunity of an inexplicable kind seems to exist which in part falls under the conception of predisposition. Even with age natural immunity varies as shown by infantile diseases. The question may be left undiscussed as to whether even these may not be considered as immunizing diseases which are said to prepare the youthful mortal for an existence surrounded by bacteria and to fortify him."

On the other hand, Alfred Wolff** explains "In all essentials the natural power of resistance to toxins advances in proportion to the organ's capacity to hold the molecules of the poison and to prevent their action on the brain. Thus only qualitative and no quantitative differences exist between apparently so diametrically opposed phenomena of an innate non-susceptibility and a high grade of susceptibility in individual animal bodies. These differences lie only in the different capacity of the organs in different animal species for the formation of toxin and an eventual neutralization."

*Fischer, A., Vorlesungen über Bakterien. 2. Ed. p. 347, Jena, Gustav Fischer, 1903.

**Alfred Wolff, Ueber Grundgesetze der Immunität, Centralbl. f. Bakteriologie, Parasitenkunde usw. Sec. I. Original. Vol. XXXVII. Part 3, p. 701, 1904.

According to our theory there is needed for the explanation of the processes of inheritance, neither any special locality such as the embryonic cells, nor any special cell or plasm germ or inheritance mass or any ancestral plasm, for inheritance is a "mechanical must" a necessary *universally* present mechanical result of the structure of the organic substance. As soon as the organic substance, like the inorganic, is considered as an atomic union which retains its character and therefore its specific peculiarities, since the atoms in the molecules exist in definite arrangements and fluctuation, then this substance presents the stage of equilibrium of *definite forms of motion.* If one cannot define the countless combinations of molecular fluctuations and cannot construct the distention and other mechanical results arising from the different arrangement, one may yet characterize each organic structure as the result of a sum of very definite combinations of molecular motions which are conditioned by each other. Accordingly the cytoplasm of the pear is a plasma whose different micellae show in general the molecular fluctuation forms of the plasmatic substances but still possess specific relations of fluctuation and arrangement which distinguish them from similarly located micellae of the apple cytoplasm. Therefore, *in each smallest particle in each biogen of any organic individual whatever, an individual character* may be found which must remain constant as an expression of the sum of definite forms of motion resulting from the law of inertia.

This constancy is a mechanical necessity;—for every motion continues in its existing form as long as it is not modified by another demonstration of force and each substance which is the expression and bearer of the motion retains this form and character until other reactions cause molecular changes[1]. If, for example, we speak of protoplasm, we must be conscious that we do not designate thereby a homogeneous substance with a fixed chemical nature, but a large group of substances containing many forms. The same is true for cellulose, sugar, tannic acid etc.

The assumption of the existence of as many variations of substances as there are individuals loses its strangeness as soon as we remember that we see about us daily an equal number of variations of figures,—for, as a fact, no one individual resembles another absolutely. If, however, each biogen is a specific unit, it retains its character with the provision that no substance coming from without may change its molecular grouping, no matter where it is located in the plant body, nor whether it occurs in the form of cellulose or as somatic or embryonic tissue. For all these substances are indeed only groupings proceeding from one another. The biogens which are utilized in the formation of the embryo, that is, at the beginning of the new generation, find an expression in the new individual as in the old for the form of fluctuation which they represent. This retention of the molecular form of motion

1 This view of the specificity of each biogen in every organism has already been expressed by Noll, since he states that the egg cell of a linden in its totality is already a linden and cannot be anything else nor become anything else. Noll, Beobachtungen und Betrachtungen über embryonale Substanz. Sond. "Biolog. Centralblatt." Vol. XXIII, Leipzig 1903, p. 325.

in the new generation is *heredity*. We are not in the least astonished to find carrot substance reproduced from carrot seed. We are also not astonished to find a table carrot produced from a carrot which is rich in sugar and not a cattle carrot rich in starch. Thus the same combinations of substances are transmitted which represent the characteristic peculiarities of our cultural varieties. If in practical agriculture we should plant side by side both of the above-named varieties of carrots we would have opportunity to observe that with the appearance of a certain degree of frost, the table carrots would freeze while the cattle carrots would remain uninjured.

The susceptibility to cold of the substance of different varieties of the same species is the most easily observed example of the inheritance of such peculiarities as represent predisposition to disease. Each fruit grower can name varieties of fruit which are injured by frost in his orchards while other varieties standing nearby are not affected or injured. The same relations are found among flowers and with grain it is a universal experience that, among the different varieties of wheat, for example, the square-heads winter-kill most easily. The same variation in the resistance of different cultural varieties is found also in relation to other causes of disease, as, for example, overheating and drought, excess of water etc. A great deal remains to be learned of the cultural varieties and their study deserves greater attention than has been given to it up to the present.

Thus cultivation has furnished us with an ornamental plant, coxcomb *(Celosia cristata)*, which has a stem with a broad, much curled vegetative tip. This broad, band-like transformation of the original cylindrical stem *(fasciation)* has become constant in the seed. Double blossoms are retained from one generation to another. Weak or one-sided formation of the sexual organs can become an hereditary peculiarity, as, for example, in the black currant or in the strawberry culture in Alten Lande near Hamburg.

From such examples one sees what far reaching differences from the usual mode of development are transmissible through the seed. Each variation indicates a direct thrust against a previously existing peculiarity which is so strong that it is able to shatter this peculiarity permanently. The peculiarities of the organism possess a varying degree of stability, i. e. the form of motion which they represent is often disturbed by a weak thrust, while in other cases it can not be changed by the strongest attacks of the surrounding factors of growth. Among the least fixed peculiarities belong the colors of the blossoms, the water and sugar content and the size proportions of the organs which can vary even in the natural habitat. Hardest to alter or cause to vary are the relative positions of the organs and the composition of the biogens, viz., the type of substance forming cabbage head or of a pear tree as such, and distinguishable from that of other plants. No peculiarity of an organism may be considered as indestructible but a number of peculiarities will be retained from generation to generation in their present form because no thrust has existed up to that time of sufficient strength to shake them. These peculiarities, however, which are ac-

cessible for factors existing at the time may succumb to the thrust according to the strength of the attack and thus be changed. These changes, because indicative of molecular transpositions, are constant as forms of fluctuation, due to the law of inertia until new thrusts give a new direction to the motion. They are retained also in the organs which we call seeds and must accordingly be continued in the new individual and therefore must be hereditary. At times also, *conditions contrary to the purpose of the individual,* and which therefore initiate the shortening of the life period of the individual, such as a lesser firmness of the substance, will be hereditary. In this sense we will have to reckon with an inheritance of diseases and of conditions which make them especially inclined to predisposition to a disease.

Besides the transference of such physiological peculiarities which promote disease in the host organism from one generation to the other, the possibility of an inheritance of parasites through the seeds of the host plant has recently been disputed. Erikkson[1], one of the most prominent investigators of rust diseases, describes a number of instances in rust of grain leaves which have led him to believe that with rust fungi embryonic developmental stages exist in which the fungi as naked plasma, *Mycoplasm,* appear united with the plasma of the host cell. Such symbiotic conditions can be present during the maturing of the seed and can exist as a dormant germ of the rust disease in the succeeding generation. With weather conditions favoring fungous development, the rust disease becomes apparent by the mycoplasmated spots transmitted by inheritance in the form then known. The extraordinary difficulty of the question as to the existence of parasites in a mycoplasmatic stage has precluded as yet any fixed decision concerning Eriksson's point of view. If the possibility of mycoplasmatic conditions must be admitted, we still think, however, that Eriksson's assuredly correct observations may have this significance since the forms described have as yet been found only near mature spore centres.

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10. Degeneration.

From time to time, especially in practical work, it is asserted generally that our cultivated plants tend to degenerate, i. e. the quantity and quality of their crops diminish, and that certain varieties run out. The degeneration of such favorite cultivated forms, said to take place simultaneously in differerent localities, is often traced to *senility* since it is asserted that even those groups of forms, which we are accustomed to call sorts or varieties, like individuals, are not able to live beyond a definite age. This point of view is supported especially by observations on our fruit trees, the varieties of which are known to be constantly propagated asexually by grafting or budding. Such varieties as a rule originate from one individual plant grown

[1] See Literature in "Zeitschr. f. Pflanzenkrankh." Annual numbers for 1903 and 1904.

in a definite region, the branches of which are at once distributed as scions. It is now thought that all individuals produced by asexual propagation actually represent only the continuation of the tree first developed from the seed. Now, since each individual has its own life period, this many-headed individual which we call a "variety" must fall victim to death after a definite length of time. In this way is explained the universally simultaneous sickening and dying out of many a variety. As examples of this kind are given Golden Pippin and Borsdorfer, two varieties of apple, on the degeneration of which there developed an extensive literature in the seventies of the last century[1].

Other old fruit varieties (especially apple) are said to suffer simultaneously from sterility wherever grown, become cankered and die. Potato varieties, formerly widely acknowledged to be excellent, are no longer true to type and disappear from the market. The orange trees found formerly in European gardens as most vigorous old specimens become diseased everywhere in spite of the greatest care. The celebrated orangeries at Sanssouci, Dresden, Cassel, Versailles etc. have vanished or are represented only by a few often sickly trees. Indeed, even in Italy, large plantations of lemon and orange trees have been attacked by diseases at present apparently incurable. The cause is said to be a weakness of growth which makes itself gradually increasingly felt, together with a diseased condition of the root. The same may be affirmed of grape vines and of olive trees, pomegranates, the Ericas (heathers) of Cape Colony, the Australian Papilionaceae and Myrtaceae, which formerly, as "Javanese" plants in special conservatories, formed the decoration and pride of gardeners. Even in our species of grains, we have noticed the disappearance of the good old varieties. This is the opinion of the representatives of the theory of degeneration.

The theory of the continuity of an individual through all the scions, for which the stock, or the parent plant rather, serves only as nurse, is based on the presupposition that this individual retains all its characteristics unchanged during its whole existence as a variety wherever grown and on the different stocks. For, at the moment when it must be granted that the habitat or stock may change any peculiarities, a variation in the length of life due to different nutrition must also be considered a possibility. For this reason those who defend the theory of degeneration and a fixed life period of varieties (especially Jensen among botanists) insist upon the fixity of characters and support their theory by the fact that the varietal character always remains constant in seeds and in cuttings as well as in grafts. Definite shoot variations produced on any one specimen (variegated leaves, split leaves, forms with weeping branches, fasciations etc.) which can always be transmitted by grafting on new stock are proofs most often stated.

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[1] "Wearing out of varieties," Gardeners Chronicle 1875. "Do the varieties wear out?" ibid. "Degeneration from senility" in the Fruit Manual 1875. "Golden Pippin degenerated" in Gardeners' Chronicle 1875. Compare "Bericht über die Verhandl. d. Sektion für Weinbau in Trier," 1875, etc., etc.

Such statements are refuted by the increasing results of grafting which show the mutual influence and change in individuals, incited by grafting. It is known that a form of albinoism, i. e. the condition of having white leaves, which we can perhaps call "marbled," is transmissible from scion to stock. Differences in the development of a scion dependant upon its being grafted on dwarf species or wild stock are known. Just as abundant are the examples of changes in size, structure, coloration and taste of the fruit according to the habitat and climate. Finally it should not be forgotten, that, in extensive cultivation of varieties, we always find some which "do not hold," that is, which from the time of germination show so weak a growth, that they soon disappear. This indicates a dying out of very young varieties. In this instance the theory of senility does not hold.

In connection with the statement that varieties of fruit formerly highly prized no longer thrive and simultaneously run out wherever grown, it is interesting to compare some reports dating from the time when the question of degeneration became one of paramount importance, which concern directly some of the varieties of fruit said to be running out. Hogg stated in 1875, in "the Fruit Manual," that Knight had complained of the "English Golden Pippin" as a variety at that time degenerating because of senility. He says that Mortimer, almost a hundred years before Knight, had spoken similarly of the "Kentish Pippin." Healthy specimens of both varieties, however, are still found in England. The length of life and strength of cultivated varieties (says Hogg) may be proved by the "Winter-Pearmain," which may be taken as the oldest English variety of apple, since it was mentioned in manuscripts as early as about 1200. The Borsdorfer apple and the well-known plum "Reine Claude," are very old.. According to Bolle[1], the "Reine Claude" must have originated in the 15th Century since it was named in honor of Claude, the consort of Louis the XII (1490).

These few examples show that the theory of degeneration due to senility of individual cultivated varieties or due to other causes has been formulated because a persistent retrogression has been observed in production and healthfulness from time to time in many localities, from which observations general conclusions have been drawn. The fact that in many regions cultivated, well-preserved forms no longer show a thrifty growth and may be replaced by others, is undeniable. But this fact only proves that, since each cultivated form makes definite demands in soil and climate, these demands can not be satisfied further in many places. Degeneration may be spoken of when a cultivated variety runs out universally, even in places where suitable conditions have been retained. However, proof of this is lacking.

The breaking down of the varieties after long cultivation may be due to twofold causes, either the cultural conditions have been changed or the character of the variety has become different. In the first place, the fact that cultural conditions in any one locality are different every year is one to

[1]Quoted in Oberdieck, Pomolog. Monatshefte 1875, p. 240, Bouché and Bolle, Monatsschrift d. Ver. z. Beförd d. Gartenb. 1875, p. 484.

which we usually pay too little attention. Aside from the fact that the weather of one year always varies from that of the preceding year, the soil too is always different; indeed partly because the time and method of working as well as the fertilization and previous cropping in themselves always effect changes, and partly because this changed arable land is also subjected to changed weather conditions, so that it differs every year physically and chemically for the same variety. In the main portion of the book a sufficient number of examples of the influence of planting, previous cropping, mechanical soil constitution and such factors will be cited and it will be shown how these can influence the character and power of resistance; as, for example, to frost.

In the second place we think that the running out of a cultivated variety can also arise because the variety itself changes its character. According to our hypothesis, there is, in all organisms, no stability; there is no strict material or formal repetition of any process, because the organism changes in the smallest unit of time, at each moment confronts the same factors of growth as a different organism and strides forward to adjustment. Thus each variety, like every term of relationship or of classification, is only a frame work made up of common characteristics in which individuals constantly fluctuate because of lesser variations.

An excess of nitrogen develops a plant substance different from that produced by moderate nitrogen nutrition, a deficiency of potassium makes an organ different from that grown with an abundance of potassium. Abundance of light and deficiency of light develop the cell wall in different ways, great warmth produces more sugar than scanty amounts of heat, etc. Exact examples are given in the chapters on the action of individual factors of growth. *Therefore the organism is like wax which, because of the thrusts of the individual vegetative factors, is constantly pressed into other material forms.*

The material constitution of the plant body, however, is changed by the variations of the molecular arrangement which we call chemical changes, as well as by the mechanical ones in which the chemical composition remains constant. The mechanical disposition of water in the tissues, the substances carried in in the water, the tension conditions in the cell wall and the cell contents, are all factors which change constantly and as constantly influence each other differently. The slightest increase in the supply of light is a thrust which not only influences the assimilatory process, but must also indirectly exercise an effect on all other functions. This does not depend at all upon whether we can define these effects;—the proof that they must take place is enough.

Let us now consider how the thrusts of individual factors of growth act normally on the plant body. Here we notice a peculiar alternation. At daybreak the action of light begins;—assimilation, evaporation, thickening of the cell wall etc. are increased, the whole structure reflects all the phenomena of the light reactions. At nightfall, when the after effects of the light have

ceased, processes of oxidation come to the front, phenomena of increased turgidity, conversion of starch and the like. The same changes may be observed in the media surrounding the plant, in the air and soil. A decrease of warmth and increase of water content must act powerfully on the plant body. With the change between day and night is associated the influence of the seasons, which forces upon the plants a period of rest after a time of production. Therefore we find in nature a *"corrective periodicity."* Amid these regularly alternating fluctuations of the vegetative factors, the plant balances its growth and completes its normal course of development.

Since the duration and action of these periods in each year differ, the production of each plant differs also and the individual years are thus characterized. We speak of dry and wet years and know from experience that in the former, the yield of grain is noticeably large, while the straw yield is less on account of the shortness of the stalks. In wet years this is reversed. And although the farmer then complains that the baking quality of the flour has suffered, yet he emphasizes the fact that he finds compensation in the greater straw harvest.

This example, taken from general practice, shows how great *single* variations in the average periodicity at once becomes noticeable since the preference is shown for different peculiarities of the plant body. As long as this kind of one-sideness in development does not threaten the existence of the individual plant we may leave the results out of consideration and seek to equalize possible cultural variations (as, for example, by the crossing of grains possessing poorer baking qualities with those rich in gluten which come from dry, warm regions).

However, the single prevalence of a definite atmospheric factor can also lead to direct disease since the *effects are cumulative.* Such an accumulation of effects may be compared to the increase in celerity in falling bodies where the distance of the fall equals the square of the time. If, instead of gravity, we assume another factor, such as wet, cloudy weather, it will in one day increase the water content of the tissue while the wall thickening remains below normal. On the second day, the first day's action is doubled and the already porous tissue becomes still more porous. The thrust against the plant body, which in itself would not produce disease, is cumulative to an extent ultimately threatening the plant's existence. Practically we find this even within one vegetative period, as, for example, lodging of the grain in rainy seasons. The moisture has lengthened considerably the cells at the base of the stalk while the deficiency of light has essentially arrested the thickening of their walls. The result is that the weakened base is not able to sufficiently resist the strain of the wind and gives way. The development of the grain is weakened or inhibited, according to the extent of this lodging and the phenomena resulting from it, so that the stalk iself is also brought to a premature death.

Corresponding to the above mechanical changes in the wall, the cell contents are subjected to changes leading to a diseased condition in the case

of other influences on the part of the vegetative factor which accumulate along one line. We find in heavily fertilized nurseries, whole plots of luxuriantly growing sweet cherries with open or hidden gum spots and in forests whole tracts and healthy looking beds of conifers which show in their wood-tissue the beginnings of a resinous condition. In garden cultures especially, which on an average are worked with the largest quantities of nitrogen, whole plantations suddenly become diseased and are abandoned because the "plants will not grow." Enough cases of this kind have reached me, in which individual breeders have announced that Begonias, *Primula sinensis* fl. pl., carnations, lilies-of-the valley, cyclamen and others which at other times under the same cultural methods had always been produced in the greatest perfection, retrogress from year to year and "degenerate." Similar conditions may be observed in field cultures. Entire fields of potato varieties which formerly gave faultless crops now easily become black specked. Sugar beets grown in the soil best suited to them tend to root rot. It has been observed in the root rot of beets that plants grown from transplants became diseased especially easily, while seedlings from the best and heaviest sugar beets showed almost no root rot. Cucumbers forced under glass, and those grown in fields in wet, cold years are spoiled by gummosis, and the like.

My experience in remedying such occurrences leads to the conclusion that *an increase* of one definite line of development is concerned in these cases which is usually called forth by excess of nitrogen and water. Our constantly increasing intensive cultivation not infrequently leads to a showy luxuriance of the plants and then to a sudden collapse, if the equalizing factor is not able to act in a corresponding amount. Accordingly in cases of a shown great nitrogen supply, I found the use of calcium phosphate to be very advantageous.

Such one-sided lines of development will also appear necessarily in the development of the seed. If it is cultivated from generation to generation under the same nutritive conditions, as when first produced, definite peculiarities of its place of growth must become hereditary through habit. According to our theory that all peculiarities of an organism represent dynamic conditions and molecular vibration-groupings, the *habit* would necessarily be explained as *inertia*. The law of inertia of all matter requires that it remains exactly in the same course and at the same rate of motion. Thus the organism keeps on vibrating as it has once been impelled, until some factor of vegetation changes the rate of its growth or the direction.

Practice utilizes this circumstance in the "change of seed," that is, in the use of seed from other places which have developed a definite desirable peculiarity. Thus the use of Swedish grain by Middle-European agriculturalists has become more extensive because it is desirable to take advantage of the shorter vegetative period of the northern varieties. While an especially developed mealy condition is typical of English wheat, regions with opposite climate conditions produce chiefly hard wheat etc.

Just as useful types of grain arise as the products of atmospheric and soil conditions, weakened conditions of the cultivated plants may also be produced locally and transmitted through seeds. If these weakened conditions are repeated from generation to generation by the persistence of causes and accumulate, they may lead in the end to a complete decline and to premature death.

Yet this is, however, no degeneration of the species or variety, for all these characteristics may be reproduced under other cultural conditions. We perceive this from the fact that the useful special characteristics introduced by a change of seed, are retained only a few years. Then the imported cultivated forms become changed and assume characteristics such as are due to the climatic and soil conditions in the place where they are cultivated. Such is also the experience in practice work which constantly attempts in some way to accustom (acclimate) highly productive species of a different climate, to some one cultural region.

If it seems desirable to apply the term "degeneration" to the above cases of the accumulation of peculiarities leading to a weakening of production and to premature death, it is possible at most only to speak of local transitory degeneration of a number of individuals. It is, however, really only a depression of the direction of development, which can be raised again by external factors, such as cultural methods. A persistent depression in growth as a result of the senility of an originally long-lived variety, is not to be assumed within any definite epoch. The disappearance of cultural varieties is explained by a decreased profitableness resulting from a deficient power of adjustment to our agricultural methods, which are constantly becoming more intensive.

SECTION 2.

HISTORICAL SURVEY.

In any branch of knowledge so young as phytopathology, any history of the science can scarcely be presupposed. And in fact the date after which the teaching of plant disease was set up as a special branch is so recent that we are still able to survey completely the course of its development.

If, however, the form of investigation is still new, the material, viz., reports on plant diseases, is very old, extending far back in history. We can not go astray in assuming that there have been diseases since the existence of the plants began and that observations on these began with their cultivation. For we constantly see what heavy injuries are produced by atmospheric extremes, and indeed not only by those disturbances which instantly kill the plant, but rather by such as weaken the individual in structure and form, and slowly lead it toward a premature death,—i. e. make it sick. The action of injurious atmospheric conditions must have existed always and have made themselves evident in different forms.

One of the oldest names which we find for certain forms of sickness, is "blight." On this account we will attempt to trace the growth of our branch of knowledge by following the observations of the diseases which this name connates.

As the later reports show, at first all those phenomena were characterized as "blight," which appeared to the eye to have the color of burned or charred matter, that is, *black*. Accordingly "blight" comprised on the one hand the groups of tree diseases, in which the dead bark assumed a blackened appearance, on the other hand also the injuries to grain, the causes of which we trace back to smut and rust fungi.

If we look first in the Bible for mention of diseases and especially of "blight," we find, for example, the following:—[1]"If there be in the land famine; if there be pestilence, blasting, *mildew*, locust, or if there be caterpillar; if their enemy besiege them in the land . . . ." Again:—[2]"The Lord shall smite thee with consumption and with a fever, and

[1] First Book of Kings, Chapter VIII, 37. Second Book of Chronicles, Chapter VI, 28.

[2] Deuteronomy, Chapter XXVIII, 22

with an inflammation, and with an extreme burning, and with the sword and with blasting and with *mildew;* and they shall pursue thee until thou perish."

From these verses Eriksson[1] concludes that these statements, which are more than two thousand years old, refer to smut and rust in grain. He cites the word Schiddafôn (heat) for mildew or blight and Jerakôn (yellowness) for rust. The following sentences already quoted by Pammel[2] point to mildew in grain:—"I have smitten you with blasting and mildew: when your garden and your vineyards and your fig trees and your olive trees increased, the palmer-worm devoured them . . . . ."[3] Descriptive of the extent of the failure in the harvest is the verse in Haggai[4]: "Since these days were when one came to an heap of twenty measures, there were but ten:—when one came to the pressfat for to draw out fifty vessels out of the press, there were but twenty. I smote you with blasting and with mildew and with hail in all the labors of your hands . . . ."

Among the Greeks, Aristotle (384-322 B. C.) mentions the years of rust and Theophrastus of Eresus (371-286 B. C.) recognized the varying susceptibility of the different varieties of grain to rust[5]. He reports also a second kind of phenomena termed blight, i. e. the bark blight of trees, since he says (Book 14, Chapter 14) that the cultivated trees are subject to several diseases. Among these, some are common to all trees while others attack only certain tree species. One universal disease is the attack by worms or by blight.

Theophrastus, whose statements, according to Kirchner[6], are certainly based on his own observations, speaks especially of the blight and canker of fig trees and mentions in this connection that diseases of trees (as of animals) seem to be determined by climate, since in some regions these same trees are healthy. The fig tree, he says further, is attacked mostly by blight and canker. Blight *(Sphakelismos),* however, is spoken of when the roots become black, canker *(Krados)* when the branches become so. *The wild fig tree, on the contrary, has neither canker nor blight.*

The statement, that some fatalities are due to the influence of atmosphere and habitat, indicates to us the cause of the disease. Such phenomena can not really be termed disease, as, for example, freezing and what some call blight. In some places certain winds also kill and burn the plants, as at Chalcis in Euboea, where the northwest wind is cold, if it blows shortly before the solstice. It blasts the trees and dries them, almost more than the sun.

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1 Eriksson, Die Getreideroste. Stockholm 1894, p. 8. (Here detailed historical reports on rust).

2 Pammel, L. H., Weems, J. B. and Lamson-Scribner, The Grasses of Iowa. Des Moines, Iowa, 1901.

3 Amos, Chapter IV, 9.

4 Haggai, Chapter II, 16-17.

5 Naturgeschichte der Gewächse. Translated and explained by Sprengel. Altona 1822. I.

6 Kirchner, Die botanischen Schriften des Theophrast von Eresos. Sond. Jahrb. f. klassische Philologie. Leipzig, 1874.

It is doubtful whether the disease mentioned here as canker bears any resemblance to the outgrowths at present called canker. It is certain, however, that woody excrescences were also observed. If actual canker swellings are not concerned here, yet the phenomena may well have been meant, which we would now call knarls. Theophrastus found this kind of swellings in olive trees and called them nails or scurf (loxas-lopas) because they represent bowl-shaped nails on the trees. Sprengel says of these nails, that they have occurred recently very abundantly on the olive trees in Italy. They appear as round, warty outgrowths of the bark, depressed in the centre like a bowl. Among them may also be found similar swellings of the wood body.

It is scarcely credible that the points of view expressed by closely observant scholars of Aristotle, concerning the phenomena of disease here mentioned, changed essentially in the course of the following centuries, for otherwise the celebrated encyclopaedist Plinius Secundus[1], who lived from 23 to 79 A. D. and who possessed a wide knowledge of literary sources, would have brought forward further material at the time he recorded scientifically the statements of Cato (de re rustica) and others as to the influence of the stars and the death of trees resulting from cold, heat, unfavorable position, soil, fertilization, incorrect pruning and the like. The discoveries set down in his "Natural History" contain much worthy of notice regarding the influence of atmospheric factors, cultural mistakes, circumstances predisposing to disease etc.

In the edition of the "Römischen Prosaiker" by Osiander and Schwab, the translator of Pliny (Külb) has given a summary of Pliny's sources and special remarks on the authors instanced in his "Natural History." There is rich material here for a complete history of phytopathology. We must content ourselves with a reference to these carefully collected Greek and Roman sources and perhaps show by only a few more quotations what extensive discoveries had been made at the beginning of our era. According to this, there may be found in the seventeenth book of Pliny's "Natural History," Part XXXVII., his statement of the action of frost. He says, "Not the weakest trees are endangered by frost, but the largest ones, and, therefore, when they do suffer, the highest tips become blasted, because the sap arrested by the cold can not reach that point." We find the following note about the phenomena, which we would now call "frost blight,"—"The evil influence of the stars depends entirely on the Heavens; on this account there must also be included among these effects, hail as well as blight and the injury caused by white frost. The blight especially attacks tender plants if, enticed by the warmth of spring, they venture to break through the ground and it singes the juicy buds of germinating plants. In blossoms this is called blasting."

In regard to carefully cultivated grape vines, one reads—"Another bad influence of the stars (atmospheric factors) is the covering with dew

[1] Plinii Secundi naturalis Historiae libri XXXVII edit. Janus. Book 17, Chap. 37.

(roration, the falling on them of cold dew. Külb) while they are in bloom, or when the berries become hard grains and spoil before they mature. They also become diseased, if they freeze and the blight injures the buds after pruning. Untimely heat has the same results, *for everything has its definite measure and goal."* At present we summarize the experiences more exactly in our teaching of an optimum and of minimum and maximum limits for the factors of growth.

In reference to defective cultural methods it is stated that diseases arise when the vine-dresser ties the vines too tightly or injures the roots when digging around them and barks or bruises the trunk. Under all these conditions they (the vines) endure wet and cold much less easily because each injury penetrates into the wound from without. Scarifying is recommended as a remedy because the thickening bark fastens the stems together and plugs them. As a protection against the frosts of winter, is mentioned the method by which water-ditches are dug about the grape vines in winter, when the ground is covered with snow, so that the cold can not blight them.

The most abundant information as to cultural methods and the evils attendant on them may be found in the collection of excerpts from old agricultural authors, which was made in the tenth century, the "Geoponika." We base our discoveries here on the books of the four well-known Roman Geoponicists, Marcus Cato, Terentius Varro, Palladius and Junius Moderatus Columella, in which special attention is paid to the practice of fertilization and grafting. A compilation of the books on agriculture by the authors here named appeared in Cologne in 1536[1].

From this work I will choose those places which show that the term "rust" as a cause of disease is of very early origin. Thus Varro mentions in the first chapter, among the gods, "qui maxime agricolarum duces sunt" . . . . "Quarto Robigum, et Floram, quibus propitiis, neque rubigo frumenta, atque arbores, corrumpit, neque non tempestive florent. Itaque publicae Robigo feriae, robigalia, Florae ludi, floralia instituti." The expression "rust" was used probably for all rust colored, diseased discolorations in plants, for we find the word Robigo used by Columella to designate a disease of grapes which can be avoided, when frost threatens, by smudging the vineyards. In his book, "de arboribus," Chapter XIII treats of: Ne rubigo vineam vexet. It is recommended "Palearum aceruos inter ordines uerno tempore positos habeto in uinea: cum frigus contra temporis consuetudinem ne intellexeris, omneis aceruos incendito, ita fumus nebulam et rubiginem remouebit." The following place is found in the "Enarratio priscarum vocum" in regard to the interchangeable usage of "Robigo" and "Rubigo"; "Robigo, deus, quem putabant rubiginem auertere, est autē Rubigo morbus segetum"[2].

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1 De re rustica M. Catonis liber I., M. Terentii Varronis lib. III., Palladii lib. XIV. et I. M. Columellae lib. XIII. Priscarum vocum in libris de re rustica enarrationes, per Georgium Alexandrinum. Coloniae, Joannes Gymnicus. Anno MDXXXVI.

2 Here, as in the following citations, we will follow our sources exactly.

The next fifteen hundred years accepted the observations and theories of the Romans, which may be found collected in Pliny. For E. Meyer[1] reports from Petrus de Crescentiis who wrote his great work in 1305, the first eight books of which treat of agriculture, that since Palladius no one had written anything in Latin on agriculture. Only fragments of the Greek collection of the Geoponika were to be found. The older works of Varro and Columella were no longer suited to existing conditions, so that there was need of an up-to-date book on agriculture. Yet the book by Petrus de Crescentiis actually contained less than the books of the older authors, although he strived for a scientific foundation for agriculture and gave numerous directions for grafting various kinds of trees, in accordance with the favorite pursuits of antiquity and of the middle ages. In the same way in 1600 Colerus[2] also only repeated the earlier statements regarding the outpushings of the bark,—"Inflammation of trees" ("Schwulst der Bewne") under which there develops a putrid liquid. In this book the influence of the stars was believed in, with unshaken firmness. For example, in his "Horticultura" published in 1631, the renowned Professor Peter Lauremberg[3] of Rostock relates that certain stars like Orion, the Pleiades and others exert an especially injurious influence and that, as a result of injurious atmospheric influences, the so-called "secret evils" arise, among which belong rust, carbuncle and mildew.

We can naturally expect to find progress in the recognition of the significance of disease among practical workers, whose cultural efforts are most sensitively disturbed by injuries making themselves felt in their work. The book of the "Electoral Superintendent of Gardens,"—Heinrich Hesze[4],—which was famous in its time, is interesting in this connection. He speaks of the blasting of the branches which he calls "blight and cold," "otherwise there are three chief causes for the blighting of trees. First, superfluous moisture which, with inflammation of the sap, is collected between wood and bark, distending the latter and blighting and blasting it. The second is this,—that oftimes, thoughtlessly and with a lack of judgment, the tree is set in a postion different from the one in which it stood before. This is very injurious, since the bark where it is brownish and has been exposed to the east or south, is therefore much harder than on the sides toward the north or west. These are generally green, tender and immature. Therefore, some injury must inevitably arise from this, since the north side is not at all accustomed to the southern sun and is not only blasted by the great heat but in the spring is injured by the hard frosts; the bark is raised, then later in the day dried up and scorched by the sun. From this the blight at once arises, since it is commonly noticed on the southern side." Here we have positive personal observations. The author relates further that he has never-

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1 Geschichte der Botanik. Vol. IV, p. 148.

2 M. Joannis Coleri, Oeconomia und Haussbuch etc. Ander Theil. Wittenberg 1600. Book V. Chapter 12.

3 Petri Laurembergii, Rostochiensis Horticultura. Francofurti 1631. Cap. XXXV.

4 Heinrich Heszens, Neue Gartenlust etc., enlarged and provided with three useful indices by Theodorum Phytologum. 1690. Chapter VIII.

theless preserved trees thus reversed in position by placing a covering of cow manure, oat chaff, glue and ashes on the side of the tree unwisely turned toward the south. "The third case, however, arises when a bread knife is used in grafting etc." Perhaps Hesze has in mind here some parasitic infection and attempts to explain it.

Hesze (p. 312) writes "that canker ("Krebs") really orginates from the grafting of a tree at the time when the moon lies in the sign of the crab or scorpion . . . ." "This disease may be recognized by the fact that here and there the bark throws up little *hummocks* under which the tissue is dead and black. This spreads further and further, ultimately infecting the whole trunk. Many scattered causes of canker have been brought forward, but the one given above is the most probable of all." The Editor makes the following addition to this statement,—"So far as canker is concerned, no one can deny that it often arises high up on the trees, and, in fact, in the accumulations of dirt which collect between the trunk and the branches at their crotches. On this account, it is most necessary that the crotches always be kept clean and freed from all dirt. Thus the canker often arises from the same rising sap which produces blight and the two diseases often have but one cause."

The author clearly describes the phenomenon which we now term limb canker and, instead of "ascending sap," we insert, injuries due to frost with a subsequent infection by *Nectria ditissima;* his presentation corresponds with our present conception of blight and canker.

About this time in France, de la Quintinye wrote "Le parfait jardinier"[1] which is still much sought after. In this we find canker briefly mentioned as a kind of gall (signifie une manière de galle ou de pourriture seiche), formed in the bark and the wood and often found on pears (Poire de Robine, Petit Muscat, Bergamotte), on trunks as well as branches. The conception of the swellings of the wood indicated by the term "canker" is found further in the writings of later horticultural authors, as, for example, in Fischer[2].

The boastful Agricola[3] (born 1672) stands independent, that is, on his personal, repeated and practical experience. His actual service is found in his numerous experiments, carried out from 1712-1715, on the vegetative reproduction of plants (especially by roots). He devotes the fifth chapter to "occurrences and diseases" and expresses himself, for example, as follows:—"Mildew, *Rubigo,* however, prevails at times, as a pestilence among trees. In spring, when the earth opens and the enclosed vapors be-

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[1] Le parfait jardinier etc. Par feu Mr. de la Quintinye. Paris 1695. Vol. I., p. 31.

[2] R. P. Christophori Fischeri soc. j. Fleissiges Herrenauge etc. Nürnberg 1719. 5 Section I., p. 168.

[3] Georg Andreä Agricolä, Philosophiae et Medicinae Doctoris und Physici Ordinarii in Regensburg. Versuch einer allgemeinen Verhmehrung aller Bäume, Stauden and Blumengewächse anjetzo auf ein neues übersehen usw. von C. G. Brausern. Regensburg 1772. The original title read,—"A new and unheard of experiment, well founded in nature and in reason, for the universal increase of all trees, bushes and flowering plants," 1716.

gin to rise, it injures most of them and is nothing else than a very sharp and biting dew, originating in the earthy vapors and conducted from them . . . . In the third place a disease occurs among trees, which is called sunblight, or blight, *uredo,* which, however, may be of two kinds. First, when a fine rain or dew falls or settles on the leaves while the sun shines, the ducts or tubes, becoming flabby and distended, are contracted at once by the heat of the sun. Thus the leaves are scorched, begin to turn brown and black and fall. In the second case, the *uredo* or blight is found in the inner parts of the trees, in the pith . . . . The true cause, however, for the blighted pith, when the tree is transplanted, may well be, that the common gardeners have the habit, in transplanting, of pruning all the roots and do not understand how much they are injuring the tree. For the smallest roots draw the most sap from the earth, and these are the ones they cut off . . . . Now because the root, together with the pith, is open and exposed, moisture can penetrate and injure the pith . . . ."

In regard to canker, we find the "ascending sap" emphasized as its cause in the horticultural lexicon by Riedel published in 1751[1]. "Canker, tree-cancer, canker, devourer," thus is listed the injurious attack on the trees which appears in the bark,—since it forms hummocks here and there and springs up.—And therefore, if the devouring evil is not overcome in time, one branch after another, and eventually the whole tree, is ruined . . . . The real cause, however, of this injurious attack on the trees is either the evil peculiarity of the earth and the evil juices produced or arising from it which become so inflamed within the bark that this looks black when removed, or the ascending superfluous rank juice, which, finding no escape, must clog and spoil, thus becoming the cause of the out-pushing and bursting of the bark."

Instead of the ascending sap, the expression—"congestion of the sap," is used at present.

As a remedy for canker, this author recommends cutting out the diseased places and coating with grafting wax. If the cause lies in the soil, this should be removed up to the roots and replaced by new soil. When the sap is excessive, the base of the tree trunk should be bored in February, and the hole wedged open for 1 to 2 days with a firm wooden peg or a strong root should be split, " since the superfluous sap will then be drawn downward."

Philipp Miller[2] traces phenomena of disease directly back to frost, and calls them "blight." Miller's decisions are essentially a repetition of Hale's theories that by blight (blast) not only frost but also sun scorch etc. are understood. Hale's[3] statements are important because he mentions the transmissability of canker in budding and of its occasional healing by being cut out. The observation of this English experimentor on the

1 Riedel, Kurz abgefafstes Gartenlexicon usw. Nordhausen 1751. p. 420.
2 The English Garden Book or Philipp Miller's "Gardener's Lexicon" etc. From the Fifth Edition translated into the German by Huth. Nürnberg 1750. p. 136.
3 Statical Essays containing Vegetable Statics etc. by Steph. Hales. 2nd edition. London 1731. I. 35ff., 147, 369; II, 265.

influence of the dry spring winds, which scorch the foliage is worth noting:—"The considerable quantity of moisture which is given off from the branches of trees during the cold winter season, plainly shows the reason, why, in a long series of cold, northeasterly winds, the blossoms and tender young set fruit and leaves are so frequently blasted in the early spring, viz. by having the moisture exhaled faster than it can be supplied from the trees."

Duhamel[1] pays great attention to injuries from frost and states that trees are often attacked by swellings which may be more easily healed in younger than in older trees. At some place on the trunk, the bark is loosened from the wood and a devouring pus occurs between the two. Devouring abscesses of this kind are called "canker" which is counted among the diseases produced by a superfluity of sap. Das Niedersächsische Gartenbuch[2] finds the cause from blight and canker in too thick standing of the trees, in unfavorable soil etc.

While in ancient times and in the middle ages observations on plant diseases were usually limited to a perception of the mature phenomena visible to the naked eye and the solution of the questions of plant life were sought almost entirely among experiments of budding, we find that the experiment itself attained its own importance with Hales and Duhamel.

Simultaneously with experimental physiology came the wider classification of plant diseases.

We follow here Seetzen's[3] treatment of the subject and its history. Seetzen states that Tournefort had a finished system[4]. His first class includes the diseases due to internal causes, as opposed to the second class, the diseases produced by external causes. To the first class he ascribes:—1-La trop grande abondance du suc nourricier; 2-le défaut ou manque de ce suc; 3-quelques mauvaises qualités qu'il peut acquérir; 4-la distribution inégale dans les différentes parties des plantes. In the second class belong:—1-La grêle; 2-la gelée; 3-la moisissure; 4-les plantes, qui naissent sur d'autres plantes; 5-la piqueure des insectes; 6-différentes tailles ou incisions, que l'on fait aux plantes.

We find Tournefort's point of view in our modern systems. We group the diseases caused by excess or deficiency of water and food, with injuries produced by weather extremes (frost, hail) etc. In the same way, we treat wounds as a separate division. The parasitic diseases appear for the first time as such in Tournefort's book.

Less fortunate is Zwinger's[5] system which appeared shortly after Tournefort's and which also is formed of two main groups,—(1) General

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1 La physique des arbres par Duhamel du Monceau. Paris 1758. p. 339.

2 Caspar Bechstedt. Vollständiges niedersächsiches Land- und Gartenbuch. Flensburg und Leipzig 1772. I, p. 151.

3 Systematum generaliorum de morbis plantarum brevis diiudicatio. Publico examini submittit Ulricus Jasper Seetzen. Gottingae MDCCLXXXIX.

4 Observations sur les maladies des plantes par M. Tournefort. Mém. de l'Ac. Roy. des Sciences a Paris 1705, p. 332.

5 Jo. Jac. Zwingeri, Diss. med. inauguralis de valetudine plantarum fecunda et adversa. Basileae 1708.

and (2) Specific diseases. The first includes:—La gangrene—le dessèchement—la surabondance de suc—le branchage excessif—une espèce de galle, qui manche l'ecorce. In the second main group we find:—Le dessèchement des racines—la separation de leur écorce—la grosseur excessive des racines, qui retienent tout le suc de la plante—les excroissances—les coups et les biessures. It is evident from this division of closely related phenomena that the author had not fully mastered his material.

Eysfarth's[1] system gives a classification which the layman easily grasps. It uses as its basis the different periods of the plant's life. In the first class are the diseases of the period of germination; in the second, those of the actual vegetative period and in the third class, the disturbances of the sexual period. Under each class are discussed the influences of weather extremes, injuries due to animals and other wounds. In this book there is also a chapter "a rubigine aut pruina." The thoroughness of the classification shows that the author had well worked out his material.

Adanson[2] returns to Tournefort's division since he sets up as his first main group the "maladies dûes à des causes externes," and as the second, the "maladies dûes à des causes internes." Even the introduction shows the advance in microscopic investigation and the increased attention paid to parasitic fungi; under the first main group, the different chapters take up, for example, Le givre ou Jivre *(Erysiphe Fabricii)*—la rouille ἐρύσιφη Theophr. (Rubigo)—le charbon (Ustilago)—la pourriture (*Caries* Fabr.) etc.

Adanson often uses the terminology of Fabricius who probably had published his studies in separate treatises before his classification had appeared as a whole, for his complete classification did not appear until 1774[3].

Fabricius certainly based his views on his own observations. This is less noticeable in the formation of the main groups than in the sub-divisions of the different chapters, in which a classification of the cases according to their different causes has been stated, even when the external appearance was similar. Thus, for example, we find in the first main group:—"Vfrugtbargiórende Sygdomme," i. e. the disturbances leading to sterility; a section "Dovhed" which may be translated by etiolation or the yellows. This is divided into D. af Regn, af Kulde, af Rôg etc. His observation that, besides rain, cold and other factors, "yellows" may be produced by ***smoke*** is also worth notice. In the second main group, "Udtaerende Sygd," i.e. the atrophias, there is found under the section "Quaelelse," etiolation from "stedets Indslutning" (too close planting), from "paa Lys" (lack of light) and from clinging plants and insect injuries. Another group is separated from these phenomena,—"Taering" (Tabes, Jaunisse in Adanson) where the yellowing is due to insufficient nutritive substances, unsuitable soil conditions, ex-

[1] Christ. Sigismund Eysfarth, Diss. phys. de morbis plantarum. Lipsiae 1723. 4°.
[2] Adanson, Sur les maladies des plantes; in "Familles des Plantes." Vol. I, p. 42. 1763. 8°.
[3] Forsög til en Afhandling om Planternes Sygdomme ved Joh. Christ. Fabricius; ind der kongelige Norske Videnskabers Selskab skrifter femte Deel. Kjöbenh. 1774. Sid. 481-492.

cessive evaporation after transplanting etc. The third main group is taken up with "Flydende Sygdomme," that is, sap-currents, under which is included honey-dew. In the fourth group are found the "Raadnende Sygdomme" which, according to our point of view, might be termed soft rot, putrefying bacteriosis or scrofula. Among the causes figure also the "Snylte-Planterne," i. e. parasitic plants. In the fifth and sixth groups, wounds, frost splits, galls and monstrosities are treated.

In 1779 appeared the German translation of the Zallinger[1] classification with the evident endeavor to utilize the terminology of animal pathology in plant pathology. Zallinger makes five classes:—(1) *Phlegmasiae* or inflammatory diseases; (2) *Paralyses seu debilitates,* laming gouts or debility; (3) discharges and draining; (4) *Cachexiae,* bad constitution of the body; (5) chief defect of the different parts. In order to characterize his theory, let us look for the disease which, with blight, forms the main example in our entire presentation,—viz. canker. Zallinger puts this in the class of the Cachexiae, in the subdivision of the ulcers, under which he includes rachitis or abortive growth, leontiasis or rough warts on the skin and others. He mentions blight, *Gangraeno s. Sphacelus* as an abnormal Cachexia, together with Phthiriasis or lousy disease and Vermiculatio, the production of worms. From this classification it may be concluded that the author has let himself be guided by the frequently similar appearance of the phenomena, for the dead places in the bark offer a favorable centre of attack by insects. What we now term grain smut is found as Ustilago, or deformity of the seed, under the class of draining. Fabricius had placed "Kraebs," Cancer, in the class of diseases of decomposition.

Batsch[2], in his introduction to the knowledge of plants, also published a survey of the diseases which he divided into those based on the "decomposition of the firm and fluid parts," i. e. on the constitution of the plant, and into those caused by "animals and plants."

Any one, however, looking for our cryptogamic parasites in the latter section would be deceived. These are rather to be found in the first class, in agreement with the conviction already advanced by Zallinger (s. Ustilago), that the parasitic organisms are not independent plants but only developmental forms of the higher plants. Thus Batsch under constitutional diseases has one group "Brandige Veränderung des Wesens," change of character due to blight, the first family of which includes the phenomenon, where a decomposition of the tissue into powder "smut, Ustilago" takes place. The second family contains the transformation of the tissues into "a spongy mass (Ergot, Clavus)."

These views remained in force for some time, as will be seen from the following section.

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[1] Abhandlung über die Krankheiten der Pflanzen, ihrer Kenntnis und Heilung; translated from the Latin by Joh. Count v. Aauersperg. Augsburg 1779. 8°.

[2] A. J. G. C. Batsch, Versuch einer Anleitung zur Kenntnis and Geschichte der Pflanzen etc. I. Theil. Halle 1787. p. 284.

By means of the works of the authors mentioned and the discoveries of practical horticulture, as well as the great sensation called forth by the tree wax for injured trees which was discovered by William Forsyth in 1791 and universally overestimated, the conviction of the agricultural significance of plant diseases was extended over so wide a circle that special books could now be published for this branch of knowledge.

The year 1795 makes us acquainted with three such works. The first one written by Plenk[1] treats of the diseases of all cultivated plants of importance at that time and is based on thorough observations. He describes thus:—"a spongy large outgrowth at some place on the trunk from which exudes, even in the most scorching weather, a caustic moisture which corrodes the whole extent of the swelling." Thus *Pyrus Cydonia,* standing near a swamp, was attacked by tree canker while other quince trees planted in a higher place were healthy. The sap, it seems, becomes so caustic from the acidity of the standing water that it eats up the ducts. There are two kinds of tree canker determined by the difference in the location of the disease; first, open tree canker, when the canker knots appear on the external surface of the bark; second, hidden canker, when a sharp cancerous pus collects between the bark and the wood but does not escape from the bark in any place. In both cases the tree becomes incurably wasted, when the parts attacked by canker are not cut out at once and covered with wound wax. In this blight Plenk distinguished between a dry and a moist blight. By the first he means "a black and dry wilting of the leaves or of some other part of the plant" and by "moist blight" he designates the "moist and soft degeneration of the plants into a putrid pus."

We find almost the same terminology in the explanation of canker in Schreger's[2] book which otherwise gives many of his personal observations. In regard to the phenomena of blight in which the bark or other parts of the tree appear black and soft and are consumed, he says, "Such black spots of the bark grow further and further round about themselves even attacking the wood so that the bark itself at last splits off, as if dead, and the wood appears dry and black, as if burned." This explanation corresponds exactly with the phenomena which we perceive when frost causes considerable injuries to the bark. In fact this observer arrives at the same conclusion as we do in regard to the cause. "Bruises from hailstones give rise to its production and also cold frosts. This frost is more injurious in low and moist regions than in high dry ones. For this reason there is less injury from frost on windy nights than on clear, cold ones. If the trees freeze in winter and die, the cause of their death is usually a blight induced by this freezing. This happens sometimes when the severe cold comes too early in the autumn while the sap is still flowing actively; sometimes in the spring when the sap, so to speak, has begun to run. The latter case is the

[1] Plenk, Physiologie und Pathologie der Pflanzen. Wien 1795.

[2] Erfahrungsmässige Anweisung zur richtigen Kenntnis der Krankheiten der Wald- und Gartenäume. Leipzig 1795.

most dangerous of all. Even in midwinter with very great cold they rarely freeze; it might be when it has rained the day before." On pages 420 and 500, he says of apple and pear trees that "an excess of fatty, oily fertilizers easily develops blight and canker," i. e. creates a *predisposition*.

The third one of the books published in 1795, the one by Ritter v. Ehrenfels[1] is even more specialized, for he treats only of fruit trees. He declares that all kinds of trees would be subject to blight and that "this decay which appears first in the bark and then in the wood" is the most common disease of trees and in some books is termed canker. The description which he gives is so clear that it can be identified as the phenomenon now known as Nectria-canker. He says, "the indication of this evil attack is first of all a black or blackish bark which, six or eight days after its appearance, is often pushed out, forms little splits and gradually loses its connection with the trunk of the tree so that it clings only loosely to the shaft. After some time the loose bark is entirely separated from the trunk and exposes the wood. In this new stage the vitality of the sick plant does its very best to help itself and unceasingly throws off the unfavorable or sick parts, but this vitality finally becomes weakened and the tree dies. The tree attempts to form a new bark *which grows in folds more or less overlapping* and tries to cover the exposed places" . . . . He ascribed the cause to injuries as, for example, from injudicious pruning, injuries due to insects and the like, *"even at times the tendency to blight* lies in the *disposition of the tree itself,*—a disposition which the trees obtain from the soil in which they grow, from their descent and from an unwise cultivation."

In the pomological glossary published at the beginning of the last century, Christ[2] added to the above by the further statement, that the blight "often is due to freezing in winter."

Burdach[3] also bases his statements on his own observations and says of blight, "this disease is an indirect result of weakness and commonly arises in those trees whose growth has been hastened by strong forcing and fertilizing or which have been transplanted to a poor garden soil where only the upper part of the ground has been improved. In cherry trees, still another evil effect arises from the same cause, viz. the exudation of resin or gum."

The theory of the influence of the soil and fertilization, as among the most important causes of plant diseases, is now laid aside for some time and attention is given to the manifold and extensive investigation of the province of fungus life.

Although antiquity had already recognized a number of edible and poisonous fungi, yet their attentive observation and systematic study began

[1] Ritter v. Ehrenfels, Ueber die Krankheiten und Verletzungen der Frucht- und Gartenbäume. Bresslau, Hirshberg und Lissa 1795.
[2] Pomologisches theoretisch-praktisches Handwörterbuch. Leipzig 1802.
[3] Systematisches Handbuch der Obstbaumkrankheiten. Berlin 1818.

first in the Middle Ages with the foundation of classification of the vegetable kingdom. According to the statements of Corda[1], Andreas Caesalpinus (1583) was the first to gather together the fungi in his celebrated book "De plantis." He describes sixteen genera, Tuber, Peziza, Fungus, Boletus, Suillus, Prunualus, Prateolus, Familiola, Scoroglia, *Fungus marinus,* Gallimaceus, *Fungus panis similis,* Lingua, Digitellus, Igniarius and Agaricum. As it seems, even marine animals have been included here. After almost one hundred years appeared Joannis Raji's "Methodus plantarum" Londini 1682. In 1710 Boërhave followed with his "Index plantarum horti Lugdano-Batavi" and in 1719 Tournefort appeared with his "Institutiones Rei herbariae."

The chief work to which modern mycology *must refer* appeared in 1729 in Micheli's "Nova plantarum genera" in which the fungi are most carefully described and illustrated in more than 100 pages and with 12 plates. Micheli studied their life phenomena more closely and was the first to observe the attachment and dissemination of spores. Among the genera there described are found those which are considered in plant diseases, Aspergillis, Botrytis, Puccinia (now Gymnosporangium), Mucor and Lycogala.

There now follow in quick succession "Methodus fungorum" by Gleditsch (1753) and the "Fungorum agri ariminensis historia" by Battara (1755), in which a special chapter treats of the usefulness and injuriousness of fungi. The close systematic description of the different genera and species begins with Linnaeus' "Systema Naturae" (1735), the "Methodus sexualis," the "Genera plantarum," the "Corollarium generum" and the "Philosophia botanica." The third edition of this book, published in 1790 by Willdenow, contains an exact list of all botanists up to 1788. The work also mentions a number of diseases (Fames, Polysarchia, Cancer, etc.). On page 245 of the present edition by Willdenow, are found the following remarks on parasitic diseases:—"Erysiphe Th. est *Mucor albus,* capitulis, fuscis sessilibus, quo folia asperguntur, frequens in Humulo, Lamio. Acere" etc. . . . "Rubigo est pulvis ferrugineus, foliis subtus adspersus, frequens in Alchemilla, *Rubo saxatili* . . . ." "Ustilago, cum fructus loco seminum farinam nigram proferunt. *Ustilago Hordei* C. B., *Ustilago Avenae* C. B." . . . Then follow notes on Ergot, galls and other malformations, changes in color etc. It is of importance to pathology that this exact systematist can not suppress the fact that really no two individuals resemble one another and that climate as well as soil constantly act in a modifying way on the organism. It is stated in fact in the Philosophia botanica, "Varietates tot sunt quot differentes plantae ex ejusdem speciei semina sunt productae. Varietas est planta mutata a causa accidentali: climate, solo, calore, ventis etc.; reducitur itaque in solo mutata." . . . . Scopoli's book "Dissertationes ad scientam naturalem pertinentes" (1772) treats especially of subterranean plants. In 1780 the publication of Bulliard's "Herbier de la France" was begun in Paris, in which the different genera are illustrated on 600 colored plates, (among others Mucor, Trichia, Sphaerocarpus, Nidularia, Hypoxylon). After

[1] Anleitung zum Studium der Mykologie.

Batch's "Elenchus fungorum" had appeared in 1783 in Jena and, between 1788 to 1791, Bolton's "Historia fungorum, circa Halifax sponte nascentium," in which only Linnean genera are described, there was published in 1790 in Lüneburg Tode's valuable work which abounds in personal observations, "Fungi mecklenburgenses selecti." The extremely careful illustrations include among others, the genera Acrospermum, Stilbum, Ascophora, Tubercularia, Helotium, Volutella, Hysterium, Vermicularia, Pilobolus which we now find among the excitors of disease. A. v. Humboldt, in his "Florae fribergensis specimen" (1793) has also described a considerable number of genera.

But all these works, nevertheless, are to be considered only "contributions." A comprehensive methodical classification was first given by Persoon's "Synopsis methodica" (Göttigen 1801), for long a standard. There appeared in England, from 1797 to 1809, a work by James Sowerby containing 439 plates of valuable illustrations with the title "Colored Figures of English Fungi or Mushrooms."

Mycologists now tended more and more toward the study of the microscopic fungous forms even if the optical instruments of the time did not make possible more exact observations. This applies first of all to Linck's "Observationes in Ordines plantarum naturales" published in the "Schriften naturforschender Freunde zu Berlin" (3. Jahregang 1809-1810) and the illustrated work by Nees v. Esenbeck, abounding in copies from earlier books, "System der Pilze und Schwämme," Würzburg 1817, which contains a summary "of the theories of the lower vegetation stages in historical fragments." Here also are the statements of investigators believing in *spontaneous generation*. The author himself, if we understand correctly his grandiloquent natural philosophical presentation, considers the parasitic fungi in the lowest possible groups as structures produced from the mother plant itself. Thus he says, for example, of the Entophytes, "Their most peculiar characteristic is that they belong to the overloaded or exhausted life and generally, if not always, develop first under the common covering without any mixture extending over the whole, and originally only in isolated places, formed individually from the life of the whole. The dependence of the infusorial cell on the higher organisms is always shown by its superior position, due to its more or less lengthened stem. The cell grows before it has become free and its elongation on this foundation is the expression of the condition of polarity which has been brought about, not suddenly but organically, and which passes over into the cell from the main plant." Under the genus Cyathus (one of the puff balls) (p. 141) it is said "the whole trunk species which we have described is only a thread of dust originating from the earth itself. The dust of the puff balls begets itself . . . ."

At this time Elias Fries[1] classic work was published including all the known varieties of the fungus kingdom with clear diagnoses of genera and species.

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[1] Systema mycologicum T. I to III. Lundae 1821, Gryphiswaldiae 1829 to 1832—Elenchus Fungorum. Gryph. 1828.

The literature now begins to be increased by single works, scientific as well as practical manuals and writings on both agriculture and horticulture which treat of diseases (Tessier, Jäger, Hopkirk, the text books of Willdenow, Nees, de Candolle, Wenderoth, Reichenbach, Re and Kieser) to such an extent that we can now emphasize only those publications which deal most fully with the history of pathology.

Among these belong primarily F. Unger's[1] "Exantheme der Pflanzen" published in 1833 and giving the results of the most industrious and conscientious studies. This physician, living in a small isolated Alpine valley, supplements his observations by many very careful original drawings, true to nature, on which he constructs his theory of disease. "Most plant diseases are located in the juices . . . . The faulty formation and the numerous abnormalities in the chemical process of the nutritive juice as well as similar faults in the more highly active life-sap, are the causes of innumerable diseases which become evident in a scanty formation of the plant substance, the accumulation of excretory substances, the breaking up of the parenchyma, the changed constitution of the secretions etc., or by conditions of an opposite character. In every case, most of the quantitatively and qualitatively changed processes of the vegetative "chylopoese" might be taken as the source of diseases which may be recognized from the change in substance rather than from that of form. The *position* into which a large number of the plants are transplanted often acts so detrimentally upon them that at least the greater part deserve to be called diseased."

Although, according to this presentation, we must suppose on the whole that Unger would consider diseases as functional and formal variations in the life-history of the organism, he, nevertheless, arrives at the conclusion that disease is something foreign. "For just as the cosmic and elementary is related to the organic, child-like, antitypical, as something parental or typical, in the same way the organism is related to the *disease which is nothing else than a second lower organism* whose elements already lie hidden in some other higher one." In this theory lies the continuation of the thought expressed by Batsch on the nature of the parasitic organisms.

Unger states that "among the plant diseases least betraying any dependence upon the organism attacked and which in their root formations are still so intimately interwoven with this organism, there belong indisputably those forms which we designate by etiolation, dropsy (anasarca), jaundice (icterus), tympanitis, tabescence (tabes), failure of crops, profluvia and others. These form in fact by far the majority. Greater independence is shown by the vast army of malformations, at the basis of which always lie *deficiencies* in the amount of sap and therefore a retardation in lower developmental stages. Honey-dew *(Saccharogcnsis diabetica)* is more important than these. Its pathological course was first recognized by L. Treviranus and its more universal significance by Dr. H. Schmidt. Mildew is indisputably related to

[1] Die Exantheme der Pflanzen und einige mit diesen verwandte Krankheiten der Gewächse. Wein 1833.

this disease: the straining toward a more complex organization of the exuded juices is made evident here by organic formations which are missing in honey-dew. These organic formations are still more independent in rust dew *(Fuligo vagans)*. Finally the disease organism appears in the excretions and the forms nearly related to them as a peculiar, complete entity. Parasites belong here—the highest among them, such as some kinds of Loranthus, seeming to have separated themselves entirely from the mother body."

Unger's views are also shared by Nees v. Esenbeck and A. Henry[1] who state in regard to puff balls that "the fungi clearly stand here at the lowest level . . . ." "They are correctly considered as the material of disease, as secretions of the higher plants." "The leaf fungus is formed in general by a coagulation of the juices discharged into the intercellular passages."

Theodor Hartig also wrote his work on the red and white rots of the pine under the influence of this theory. In this he confirmed first of all the co-operation of fungi (Nyctomyces)[2]. He traced the production of these fungi to a decomposition of the cell walls.

Of the works which take up general constitutional diseases and scarcely touch upon the fungi, we will name those by Geiger[3] and Lindley[4] which in all essentials are based upon practical experience. On the other hand, however, Wiegmann's[5] statements are evidently based on microscopic studies and the bearings of chemistry, for example, he states that the pus of the blight, as well as that of canker, contains putric and humic acids, but that that of the blight contains more putric acid. To him both diseases appear non-parasitic in nature and he thinks canker (Caries, Necrosis) always arises from "a stoppage and deterioration of the juices, even if these were never present in excess." Among the causes mentioned are injuries to the roots, or injuries from frost and unfavorable soil conditions, as, for example, "If the subsoil is moist, sour, stony or otherwise unfertile, or contains swamp ore."

Meanwhile, after Corda's[6] great work on fungi had begun to appear, Meyen's[7] "Pflanzenpathologie" was published as a standard, which even now warrants consultation. He divides his material into "External Diseases" and "Internal Diseases." Among the former, besides the injuries due to man and to animals, the formation of gnarls and galls, he includes also phanerogamic and cryptogamic parasites, of which the Ustilagineae and the Uredineae as well as other fungi are treated in detail, according to

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1 Das System der Pilze, Section I. Bonn 1837.

2 Abhandlung über die Verwandlung der polycotylen Pflanzenzelle in Pilz und Schwammgebilde und die daraus hervorgehende sogenannte Fäulniss des Holzes. Berlin 1833.

3 Die Krankheiten und Feinde der Obstbäume. München 1825.

4 The Theory of Horticulture. London 1840.

5 The Krankheiten und krankhaften Mifsbildungen der Gewächse von Dr. A. F. Wiegmann sen. Braunschweig 1839.

6 Icones Fungorum hucusque cognitorum. Prague 1837 to 1854.

7 Pflanzenpathologie. Lehre von dem kranken Leben und Bilden der Pflanzen. Published after the death of the author by Dr. Gottfr. Nees v. Esenbeck, Berlin 1841.

the standpoint of the time. Meyen no longer shares Unger's view that the parasites as excrement-organisms are the product of a formative development latent in each plant, the disease occurring in a more or less developed form and state of independence according to the constitution and strength of the host-organism. On the contrary, his Plant-Pathology, in the discussion of smut fungi, emphasizes especially that "observations on the production of the smut show most clearly that we have to do here with true entophytes: we will find that some smut species are shown as particular parasitic growths in the interior of the cells of the plants attacked by them and that the smut mass is not to be compared with animal pus."

The whole title of Meyen's "Plant Pathology" really reads:—"Handbuch der Pflanzenpathologie und Pflanzenteratologie" edited by Dr. Chr. Gottfr. Nees v. Esenbeck. Vol. I, "Plant Pathology." According to this, a second part, Teratology, was to be expected. Meyen himself intended to work up such a volume, but, according to the Editor, left no material for it. Just as Nees v. Esenbeck was about to undertake this himself, there appeared the "Eléments de Tératologie végétale, au Histoire abrégée des anomalies de l'organisation dans les végétaux; par A. Moquin Tandon, Doct. sciénc. et méd. etc., director du jardin des plantes de Toulouse. Paris 1841." C. F. Jaeger "Ueber die Missbildungen der Gewächse" (1814) and Thomas Hopkirk. "Flora Anomala" (1817) should be mentioned as forerunners of this work. We learn from the German translation of Moquin Tandon's[1] book, that the translator, C. Schauer, was able, as specialist, to call attention to many misunderstandings and errors made by the author, especially in the German citations and to make additions from his own observations. Moquin Tandon says, "By the expression 'malformations', 'monstrosities' (monstra) is generally understood innate, more or less important and complicated variations from the type of a species, which are disfigurations and oppose the regular course of a functioning by hindering or arresting it." We are better satisfied by de Candolle's definition (Theor. élément. I. éd. p. 406), by which monstrosity is any disturbance in the economy of a plant, which is followed by a change in organic form and arises from an internal disposition, almost never from a visible cause. Moquin Tandon's book is still indispensible to every specialist because of its admirable bibliographical references.

About this time, the science of infectious diseases received a new impetus because of the rapid spread of the potato disease which is still worthy of especial attention. It is one of the most dreaded enemies of agriculture, and is described in the text books as potato Phytophthora rot. We owe one of the first publications on this subject to Martius[2] and from that

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[1] Pflanzenteratologie. Lehre von dem regelwidrigen Wachsen und Bilden der Pflanzen. By A. Moquin Tandon. Translated and supplemented by Dr. J. C. Schauer. Berlin 1842.

[2] Die Kartoffelepidemie der letzten Jahre. München 1842.

time on a flood of publications, proportionate to the very severe injury to national property from these diseases. We will emphasize among these publications only those of Focke[1], Payen[2], Schacht[3], Speerschneider[4], v. Holle[5], Kühn[6] and de Bary[7]. (Further bibligraphical references may be found in the detailed discussions of the different diseases).

It was natural that a phenomenon, such as the potato epidemic, would necessarily bring fungous diseases into prominence and increase the whole study of mycology. At the same time the economic importance of smut fungi also began to receive greater and greater consideration. Tillet[8], Tessier[9], and Prévost[10], had early studied the smut of grains and at present we have acquired a considerably extended insight into the nature of those diseases and also into the means of combatting them from de Bary's[11] investigations and Brefeld's studies, extending over many years. The prevalence of smut diseases has led to the development of the sterilization of seed.

In the second volume of this work, which treats of parasitic diseases, the overpowering number of mycological works will be mentioned,—we will here mention only some of the most important ones, treating of fungus families as a whole. Elias Fries' great work completed in 1832, has already been considered. In 1831 the first part of Wallroths "Kryptogamenflora"[12] appeared and in 1833 the second part. In this book the cryptogams were worked up by Math. Joc. Bluff and Carl Ant. Fingerhuth. In 1842 Rabenhorst's "Kryptogamenflora"[13] began and in 1851 Bonorden's "Handbuch der Mykologie"[14], which has proved to be very useful because of its cuts of microscopic fungus forms, although these had been sufficiently considered in the illustrations of Schäffer, Persoon, Greville, Sowerby, Sturm, Krombholz and Nees sen. To be sure Corda's "Icones fungorum" had already been published and his "Anleitung zum Studium der Mykologie"[15] which is provided with very small drawings; leaving the peculiarity of his classification out of the question, however, Corda limited himself to the easily visible developmental stages, while Bonorden sought to determine the tissue structure. This author, in opposition to Unger, emphasized the fact that parasitic fungi are unquestionably independent organ-

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1 Die Krankheit der Kartoffeln im Jahre 1845. Bremen 1846.

2 Les maladies des pommes de terre, des betteraves, des blés et des vignes. Paris 1853.

3 Schacht, Bericht über die Kartofflépflanze und deren Krankheiten. Berlin 1854.

4 Das Faulen der Kartoffelknollen. Flora 1857. Bot. Z. 1857.

5 Ueber den Kartoffelpilz. Bot. Zeit. 1858.

6 Die Krankheiten der Kulturgewächse, ihre Ursachen und Verhütung. Berlin 1858.

7 Die Kartoffelkrankheit. Leipzig 1861.

8 Dissert. sur la cause qui corrompt les graines de blé, 1755.

9 Traite des maladies des graines, 1783.

10 Mémoire sur la cause de la carie des blés, 1807.

11 Untersuchungen über die Brandpilze. Berlin 1853.

12 Flora cryptogamica Germaniae auctore Ferd. Gull. Wallrothio, Med. et Chir. Doctore etc. Norimbergae 1831-33.

13 Kryptogamenflora von Deutschland, Vol. I., Leipzig 1844. 2nd Edition. I-VII. 1884-1903.

14 Handbuch der Allgemeinen Mykologie etc. with 12 plates. Stuttgart 1851.

15 Anleitung zum Studium der Mykologie nebst kritischer Beschreibung aller bekannten Gattungen. Prag 1842.

isms, but maintained that "it is the stomata which take up the spores and bring them to development in the air cavities connected with them." He said that algae, lichens and mosses which have no stomata and, for the same reason, young branches and twigs are free from parasites. He expresses his point of view in regard to the action of parasites, as follows:—"That they first cause an hypertrophy and degeneration of the parts heavily infested with them but when isolated they do not disturb the growth of the leaves." According to him, dry weather is essentially propitious for the spread of the parasites, "because it favors the scattering of the spores. On this account Caeoma and Phragmidium are never found more abundant than in dry summers, as also the *Caeoma cerealium,* the yellow corn smut so injurious to seeds, which caused such great damage in 1846."

Kühn in his "Krankheiten der Kulturgewächse" (Berlin 1858) attained, in the happiest manner, the end for which Meyen strove, viz. of uniting scientific studies with practical experience in the treatment of plant diseases. However necessary and important purely scientific investigations may always be in phytopathology, yet they achieve their full significance only by being tested in practical agriculture. Only by practical work can it be decided whether the conditions of nature and of the laboratory favor the development of the same parasites or other excitors of disease. So it is necessary to build phytopathology upon a practical knowledge of agriculture and horticulture. The differences which have developed in medicine between the scientific investigator and the practicing physician must also necessarily arise in the science of plant diseases. We term this practical side,—the profession of "Plant Protection."

Mycological studies are a part of the indispensible fundamentals of plant protection and for this reason, we have given them the greatest possible attention in the history of phytopathology. Continuing with this in view we will name first of all the masterly plates in the book by the brothers Tulasne "Selecta fungorum carpologia," Paris. The English work by Berkeley "Outlines of British Fungology," London 1860, is most welcome as a collective work although it is mostly provided with very rough illustrations. De Bary's works continue to be of especial value. His results in this connection may be found summarized in the "Morphologie und Physiologie der Pilze, Flechten und Myxomyceten," Leipzig 1866.

We owe further important investigations to O. Brefeld, in his "Untersuchungen über die Schimmelpilze," Leipzig 1871, 1872 and following, and Cohn for his "Biologische Mitteilungen über Bakterien," Schlesische Ges. f. väterl. Kultur, 1873, as well as for his "Untersuchungen über Bakterien" 1875 and for other studies contained in his "Beiträge zur Biologie der Pflanzen." In these Cohn has successfully advanced the history of the development of Bacteria. His pupil, Zopf, essentially extended these studies in the work "Die Spaltpilze," Breslau (3rd Ed. 1885). Among the summaries of this time mention should be made of Eidam "Der gegenwärtige Standpunkt der Mykologie mit Rücksicht auf die Lehre von den Infektionskrankheiten,"

Berlin (2nd Ed. 1872) and further Winter, "Die Pilze Deutschlands, Oesterreichs und der Schweiz," Leipzig 1884. Rabenhorst's "Kryptogamenflora" brings the subject to completion.

The most comprehensive systematic summary of all the fungi is contained in P. A. Saccardo's "Sylloge Fungorum." The eleventh volume with a "Supplementum universale" was published in Pavia in 1895. Sydow's "Index universalis et locupletissimus nominum plantarum hospitium speciarumque omnium fungorum," Berolini, Fratres Borntraeger 1898, carries the work further. This book contains all the fungi known up to 1897. Further supplemental volumes (XIV-XVI) were published in 1899-1902 and others are to follow. Saccardo supplemented this great work on fungi with 1500 illustrations which were published from 1877-1886 under the title "Fungi italici autographice delineati," Patavii.

In place of the sketchy drawings of this work, A. N. Berlese began to publish a series of most careful, colored illustrations under the title, "Icones fungorum ad usum Sylloges Saccardianae adcommodatae," Abellini. The *Sphaeriaceae Hyalophragmiae* were furnished in parts IV-V, which appeared in 1894. To our knowledge, the author had not finished the work at the time of his untimely death. In the same way, we find colored illustrations in Cooke's "Mycographia seu Icones fungorum," London:—the first part appeared in 1879 with cuts of the discomycetes.

The publications on fungi and bacteria now become so numerous that they are no longer to be mastered and make any further citations impossible. This compels us to refer to the *"Botanischer Jahresbericht"* which has been appearing since 1873.

It is natural that Teratology has also developed further since Moquin Tandon. Among the works treating of the material as a whole, emphasis should be laid on M. Master's "Vegetable Teratology," London 1869 and O. Penzig, "Pflanzenteratologie," systematisch geordnet, Genua 1890-94, which may be designated as the most complete book of reference on this subject.

Because of limited space we must forego all further citations of mycological literature. The reader will find the desired supplementary information in the second volume of this work. However, a brief reference to the numerous publications descriptive of fresh and herbarium material must be made in a presentation of the history of the development of this science. Among the herbaria which pay especial attention to plant diseases, there should be mentioned here, F. v. Thümen, "Herbarium mycologicum oeconomicum," Teplitz, 1873-79, Rabenhorst, "Fungi europaei exsiccati" continued by Winter and Patzschke; L. Fuckel, "Fungi rhenani exsiccati," 2nd Edition 1874; Jak. Eriksson, "Fungi parasitici scandinavici," Stockholm 1882-1895; G. Briosi et F. Cavara, "J funghi parassiti delle piante coltivate ed utili essicati, delineati e descritti," Pavia, fasc. I-XII (1897); W. Krieger, "Schädliche Pilze unserer Kulturgewächse," fasc. I. 1896; A. B. Seymour and F. S. Earle, "Economic Fungi, Cambridge. Following in close connection with Rehm's ascomycete collection, published many years ago, are many

Herbaria representing the general fungus flora of different countries, as, for example, those by Saccardo, Sydow, Vestergren, J. B. Ellis, Jaap, Bubák and Kabat, Pösch etc.

Although the science of plant diseases would refer to teratological phenomena only when it can prove, or at least suppose as a cause of the individual phenomena, some definite disturbance of nutritive or structural conditions, it has been forced to take the animal world more and more thoroughly into consideration. The following publications summarize the entire material or the larger part of it, are comprehensive and should be used for further study:—Ratzeburg, "Die Forstinsekten," Berlin 1839-1844 and "Die Waldverderbnis," Berlin 1866-1868; A Gerstäcker, "Handbuch der Zoologie," Vol. II., Arthropoden, Leipzig 1863; E. L. Taschenberg, "Entomogie für Gärtner und Gartenfreunde," Leipzig 1871, and "Die der Landwirtschaft schädlichen Insekten und Würmer," Leipzig 1865. Further Nördlinger, "Die kleinen Feinde der Landwirtschaft," Stuttgart 1869. Kaltenbach, "Die Pflanzenfeinde aus der Klasse der Insekten," Stuttgart 1874, and Ritzema Bos, "Tierische Schädlinge und Nützlinge," Berlin 1891. The "Handbook of the Destructive Insects," by C. French, published in Melbourne in 1891 by order of the Department ofAgriculture of Victoria, is less rich in material but better adapted to the practical needs of the layman, because of its colored plates.

In the same year H. R. v. Schlechtendal published a smaller special work on gall formations,—"Die Gallbildungen (Zoocecidien) der deutschen Gefässpflanzen," Zwickau 1891. Ten years later G. Darboux and C. Houard published a comprehensive systematic work,—"Catalogue systématique des Zoocécidies de l'Europe et du Bassin méditerranéen," Paris 1901.

The "Forstliche Zoologie" by K. Echstein, Berlin 1897, may be especially recommended because of many careful original drawings. The popular writings of H v. Schilling are especially useful for horticulture; we recommend "Die Schädlinge des Obst-und Weinbaues," "Die Schädlinge des Gemüsebaues," Frankfort a. O. 1898 and the "Practischer Ungezieferkalender," Frankfurt a. O. 1902. The "Schutz der Obstbäume gegen feindliche Tiere" by E. L. Taschenberg (3rd Edition by O. Taschenberg), Stuttgart 1901, is also well adapted for practical needs.

As the science of plant protection develops there is a corresponding attempt to produce reference books treating some of the most important cultivated plants, such as Eisbein "Die kleinen Feinde des Rübenbaues, 1882, with carefully prepared colored plates and Emile Lucet "Les insectes nuisibles aux Rosiers sauvages et cultivés en France," Paris 1898, with numerous plates in black and white. Most complete is the work being done in the United States in protecting plants from these animal enemies. The Zoologists in the several State Experiment Stations and the "Bureau of Entomology" of the Federal Department of Agriculture in Washington, are advancing rapidly the study of the enemies of cultivated plants, by new investiga-

tions and by the distribution of popular treatises. More detailed references to zoological literature are to be found in the third volume of this manual.

The number of text-books and manuals of phytopathology has gradually been increased since the publication of Kühn's "Krankheiten der Kulturgewächse," as the understanding of the national economic significance of phytopathology has increased. First of all comes Örstedt's "Om Sygdomme hos Planterne, som foraarsages af Snylteswampe, navnlig om Rust og Brand," Kjöbenhavn 1863. This work was followed in 1865 by later reports on the alternation of hosts by rust fungi *(Gymnosporangium Sabinae).* About this time Hallier's[1] book appeared which must be given more especial attention in a history of plant diseases because of the author's standpoint. Hallier's views leading to sharp literary disagreements, especially with de Bary, may be found in extenso in his later writings[2]. In his "Pestkrankheiten der Kulturgewächse," he gives a list of investigations on the Peronosporeae and believes he has permanently established by these the correctness of his *"Plastiden Theory."* At the time of the "Cholera meeting" in Weimar (1868), Hallier first made the assertion that the forms, summarized as Fission fungi (Schizomycetes) by Nägeli were not independent organisms, but represent the products of the plasma of different groups of filament fungi. Hence Nägeli's family of the Fission fungi should be stricken out of the classification and infectious diseases as a whole be traced back to the action of such plasma-products ("Plastiden"). "In order therefore to discover the origin of infectious diseases, it is necessary in every case to ascertain by investigation which definite fungus produces the cells of contagion from its plasma (bacteria, micrococcus etc.) and in what way this takes place." In regard to the potato disease produced by Phytophthora, he does not question whether this fungus is the cause of the disease, but only whether it may cause it less directly than would bacteria. "I have proved first and foremost that the bacteria which are the absolute cause of the potato pest, are produced by the "Plastiden" of the Phytophthora and that these, when once formed, are absolutely equal to the production of the plague; that there is no further need of the mycelium and buds of the Phytophthora." His numerous experiments ultimately led him to the view that, in all infectious diseases, human, animal and vegetable, three main points undoubtedly come under consideration: (1) The absolute cause; (2) External or general furtherance (chance causes or *predisposition*); (3) Personal furtherance (susceptibility of the diseased individual).

Sorauer in the first edition of his "Manual of Plant Diseases," Berlin, Paul Parey, 1874, first introduced into plant pathology the view, that in all diseases not only the direct cause but also the earlier preparatory stages and, in parasitic attacks, the accessory conditions favoring the development of the parasites, including the disposition of the host organism, should be taken

1 Phytopathologie. Die Krankheiten der Kulturgewächse. Leipzig 1868.
2 Die Plastiden der niederen Pflanzen. Leipzig 1895.—Die Pestkrankheiten (Infektionskrankheiten) der Kulturgewächse. Stuttgart 1895.

into consideration. This statement was definitely established in the second edition (1886) and in an abstract written especially for the practical agriculturalist, "Die Schäden der einheimischen Kulturpflanzen," 1888. The delayed acceptance of these ideas is shown by the text-books which immediately followed. Of these the one especially valuable because of its numerous personal investigations is "Lehrbuch der Baumkrankheiten" by Robert Hartig, Berlin 1882 (2nd Ed. 1889). The third edition, in which the author rather unreservedly acknowledges a predisposition and differentiates local, temporal, individual, acquired and morbid predisposition, appeared in 1900 with the title "Lehrbuch der Pflanzenkrankeiten"—Berlin, Julius Springer. A study of the phenomena of the decomposition of wood, with the title "Wichtige Krankheiten der Waldbäume," Berlin 1874, is an introductory work for this textbook.

Sorauer's Manual was followed first by Frank's detailed elaboration, "Die Krankheiten der Pflanzen," Breslau 1880 (2nd Ed. 1895). The "Lehrbuch des Forstschutzes" by H. Nördlinger, Berlin 1884, is devoted especially to cultivated forest plants. Solla's book, "Note di Fitopathologia," Firenze 1888, is more comprehensive and contains an atlas. This was preceded in Norway in 1887 by Brunchorst's "De vigtigste Plantesydomme." To this decennium belongs also a number of noteworthy articles by Jensen, among which (according to Rostrup) is: "Kartoffelsygen kan overvindes ved en let udforlig Dyrkningsmaade," Kjöbenhavn 1882.

While up to this time scientists had classified diseases according to their proved or assumed causes, Kirchner in 1890 published "Die Krankheiten und Beschädigungen unserer landwirtschaftlichen Kulturpflanzen," Stuttgart, arranged especially for practical use. The diseases are listed here according to the different cultivated host plants and described according to their visible habit of growth. Systematic scientific supplements are collected at the end of the book. In accordance with the line of investigation of this author there appeared in 1895 a richly illustrated book treating of parasitic diseases only,—"Pflanzenkrankheiten, durch kryptogame Parasiten verursacht," by Karl, Freiherr v. Tubeuf, Berlin, Julius Springer. Parastism was here developed as a form of symbiosis and thereby referred to an "internal and an external" predisposition for becoming diseased. The internal predisposition depends on "the energetic condition of the living protoplasm of the host cell," while the external one "is determined especially by anatomical conditions." In the same year Prillieux published a two volume work abounding in personal investigations, "Maladies des plantes agricoles et des arbres fruitiers et forestiers," Paris. This, the most comprehensive work in French on the subject, describes only parasitic diseases. They are treated scientifically and yet the practical side receives attention in so far as means for combatting disease are considered.

An unlooked-for advance in the studies on bacteria resulting from their many-sided economic significance, made a revision and enlargement of de Bary's "Vorlesungen über Bakterien," necessary. In 1900, in Leipsic, Mig-

ula, enabled by his own work, produced a new edition to which he added exact bibligraphical citations.

Meanwhile, as the necessity of familiarizing practical circles with the nature of plant diseases became increasingly more evident, it led the large German Agricultural Society to undertake the issuing of suitable publications. In 1892 appeared the first edition of Sorauer's "Pflanzenschutz," and in 1896 its second edition, revised by A. B. Frank and P. Sorauer. The authors strived for the briefest presentation possible, classified the diseases according to the host plants and treated each disease under three headings:—Recognition, Production and Control. The text was supplemented by numerous illustrations on colored plates. In the same way, Frank published a more detailed work with the title:—"Kampfbuch gegen die Schädlinge unserer Feldfrüchte," Berlin 1897 and Sorauer one, entitled, "Schutz der Obstbäume gegen Krankheiten," Stuttgart 1900, provided with numerous figures in the text.

Of books in foreign languages, there appeared about this time, W. Krüger's treatise on the diseases of sugar cane in the "Bericht der Versuchsstation für Zuckerrohr in West-Java, Kagok-Tegal," published in 1896. This treatise took up thoroughly the Sereh disease with a conscientious use of the pertinent literature. Subsequent to it appeared in Leyden in 1898, H. Wakker and G. Went's "De ziekten vom het suikerriet op Java," which should be recommended because of its many plates.

Delacroix treats the diseases of coffee especially in his book, "Les maladies et les ennemis des Caféiers," Paris (2nd Ed. 1900). Two years later D. McAlpine, in Melbourne, published "Fungus diseases of stone-fruit trees in Australia."

The last named publication considered cultivated plants only. The need of a comprehensive treatment of the whole field of diseases was shown and after a long interval, a response, the manual, "Plantepatologi" Haandbog i Laeren om plantesygdomme af E. Rostrup, was published at Kjöbenhavn in 1902. This book, elegantly gotten up and attractive because of its many careful original drawings, lays emphasis on fungous diseases, the known number of which the author by his many personal observations, published after 1871, had increased. To facilitate the consultation and discovery of the different diseases, a list was placed at the end of the book, arranged according to the host plants.

In 1903 the Japanese published a book which should be considered as a significant cultural advance. We have a German translation of this entitled "Lehrbuch der Pflanzenkrankheiten in Japan," Ein Handbuch für Land- und Forstwirte, Gärtner und Botaniker. Von Arata Ideta (3rd Ed.) Tokio 1903). This work is provided with a glossary of technical terms in German, English and Japanese and contains 13 plates and 144 text figures carried out in fine line-drawings (mostly after German authors).

In a science like phytopathology, in which the results of all investigations are intended for use in practical industry, the need is at once felt of

making the forms and causes of disease more easily comprehended by the layman, by means of colored illustrations. On this account, without regard to special works on fungi, we often find the text supplemented by colored pictures of the habit of growth. An attempt to present the most important diseases in the form of a portfolio with short descriptions of the figures on the plates could be undertaken only after a more widely extended understanding of the importance of this branch of knowledge had insured a sufficient number of purchasers. Accordingly, since 1886, Paul Parey of Berlin has issued Sorauer's "Atlas der Pflanzenkrankheiten," of which six folio numbers have already been published. The especial care used here, in having the different colors true to nature, made the price such that the publication had a smaller circulation among practical workers than in scientific institutes, and accordingly a need was gradually shown for the publication of a less expensive work. This appeared under the title, "Atlas der Krankheiten und Beschadigungen unserer landwirtschaftlichen Kulturpflanzen," edited by O. Kirchner and H. Boltshauser and published by Ulmer, Stuttgart. This is now completed in six numbers. Meanwhile the Deutsche Landwirtschafts-Gesellschaft discovered, by its publication of "Pflanzenschultz," that at present the time is ripe for the extension of the knowledge of diseases among practical agriculturalists, and that it can be carried through most successfully by such brief guides. The society published the third edition in 1904, revised by Sorauer and Rörig, with seven carefully prepared plates. The "Atlas des Conférences de Pathologie végétale" by Georges Delacroix, Paris 1901, should be mentioned as of special service to the systematic study of diseases. This gives the most important diseases of cultivated plants in 56 plates in black and white. In 1902 Delacroix published by order of the French Agricultural Department a small work, "Maladies des plantes cultivées," Paris, which was written chiefly for general use and is supplemental to the above.

The most significant scientific advance is the publication of monographs covering the separate fields of disease. This method has also appealed especially to recent workers in plant pathology. In accordance with the importance of the disease, thorough study has been devoted to the rust fungi, especially of grain. In 1894-95 the German edition of a 463-page work by Jakob Eriksson and Ernst Henning was published,—"Die Getreideroste, ihre Geschichte und Natur, sowie Mafsregeln gegen dieselben," Stockholm. This work, which attracted much attention, appeared as a volume of the "Meddelanden från Kongl. Landtbruks-Akademiens Experimentalfält," and its 13 colored plates show clearly the diseases due to grain rusts. It proves the specialization of parasitism in the fungi of grain rusts. Besides this, the work takes up the discussion of the determinative factors and tests the position, the physical and chemical constitution of the soil, the previous cropping, time of seeding etc.

In 1904, H. Klebahn published an equally careful work with a larger field and based on his personal studies, entitled:—"Die wirtswechselnden

Rostpilze," Versuch einer Gesamtdarstellung ihrer biologischen Verhältnisse. Berlin 1904. Gebr. Bornträger. A chronological table gives a list of the heteroecious rust fungi discovered since de Bary's first investigations made in 1864 with *Puccinia graminis*. The text treats in the greatest detail and with pertinent bibliographical references, gradation of differences, limitation of species, specialization and theory of descent, susceptibility and transmission of rust diseases in seed. With this is also discussed thoroughly the mycoplasm theory brought forward about 1897 by Eriksson. This point has already been discussed (see p. 34). Eriksson's latest studies appeared in 1904 in the publications of the Schwed. Akad. d. Wissensch. under the title: "Das Vegetative Leben der Getreiderostpilze."

A further important advance in the creation of scientific foundations is shown in the "Pathologische Pflanzenanatomie" by Ernst Küster, Jena 1903, published by Gustav Fischer. Guided by the discovery that a distinct separation of the natural forms into normal or abnormal can not be carried out, Küster tests the phenomena from the physiological point of view, i. e. as to the functional efficiency of the tissues. "The tissues are prevented from developing into functionally efficient, i. e. normal tissues, by influences of some kind or functionally efficient tissues undergo subsequent changes in which they forfeit entirely or partially their functional ability, or new tissues are produced in the plant body of such a nature that its diseased and deformed organs either accomplish nothing for the organism as a whole, or less than those which we designate as normal." We find in this work a successful attempt at presenting the *developmental mechanics* of the vegetable organism.

A *periodical literature* developed along with the attempts to organize the protection of plants. The guiding principle was the practical question, how the spread of disease and the enemies of cultivated plants may best be prevented and how their direct control can be most advantageously accomplished.

This question was considered more closely first in the United States of North America, since in 1887 stations were formed by the Department of Agriculture for the study of phytopathology and of insects. These most active institutes and experiment stations first of all issued annual reports and then later special publications of scientific investigations. The report of 1889[1] gives a closer insight into the organization of the service. We learn from it that the Phytopathological Division published its investigations in a definite periodical "The Journal of Mycology" and also distributed popular bulletins of some of the most important diseases. Correspondence consisting of replies to queries consumes much of the activity of these stations. For example, in 1889 the questions sent by practical agriculturalists demanded 2500 replies. These scientists desire chiefly to test results of lab-

1 Report of the chief of the Division of Vegetable Pathology for the year 1889. Published by the authority of the Secretary of Agriculture. Washington 1890.

oratory studies by field experiments. With the intention of carrying out such practical agricultural experiments, the pathological division has installed certain supervising agents. When the results of such experiments, conducted in the open in different regions, corresponded sufficiently well, general conclusions were drawn and the results published as speedily as possible.

In Germany the first attempt toward organization was shown at the Agricultural Congress in Vienna in 1890, where Eriksson and Sorauer brought forward a proposition recommending to the government regulations similar to those already carried out in America. With the intention of working out a special plan and the development of effective activity, an "Internationale phytopathologische Kommission" was formed by representatives of all European agricultural countries and Sorauer, as secretary, was commissioned to bring out suitable publications. This furnished an incentive for the foundation of the *"Zeitschrift für Pflanzenkrankheiten"* the first annual series of which appeared in 1891. In the same way the interest in establishing experiment stations and similar institutions for the special cultivation and the protection of plants in different countries, was stimulated and successful. In 1880[1] Korn-Breslau published in Prussia a very thorough report, "Ueber die Begrundung einer wissenschaftlichen Centralstelle behufs Beobachtung und Tilgung der Feinde der Landwirtschaft aus dem Reiche der Pilze und Insekten." The Imperial Government should have responded to such stimuli through the German Agricultural Council. In June, 1889, Julius Kühn, through whose endeavors the experimental station under Hollrung was established in Halle a. S., brought this same subject before the German Agricultural Society and in 1890 the Society established a "special committee for the protection of plants" whose Board of Directors was formed by Julius Kühn, A. B. Frank and P. Sorauer. This special committee established a net-work of information bureaux for practical agriculturalists which covered the whole German Empire, and published successive *"Annual Reports from the special committee for the protection of plants,"*[2] after Sorauer had begun in 1891 a statistical revision of the rusts of grains.

In 1890 the Phytopathological Laboratory at Paris was opened under Prillieux and Delacroix and in Amsterdam on the 11th of April, 1891, the Netherland section of the International Phytopathological Commission was established. This commission called Ritzema Bos to Amsterdam in 1895 as director of the "Phytopathologisches Laboratorium Willie Commelin Scholten." In this year, at the instigation of the Holland Phytopathological Association and of the Phytopathological Division of the Botanical Society Dodonaea, the "Tijdschrift over plantenziekten," edited by J. Ritzema Bos and G. Staes was published. Meanwhile, an experimental station was founded at the Pasteur Institute for the purpose of combatting injurious animals by means of contagious diseases. In 1894 this was placed under the direction of Metschnikoff. As director of the "Experimentalfältet" at Albano, near Stockholm, Eriksson was untiringly active. In 1895 he published test ex-

[1] Archiv des Deutschen Landwirtschaftsrates, Part 8, p. 307.
[2] Jahresberichte des Sonderausschusses für Pflanzenschutz.

amples for the special forms of grain rusts after which, in February 1901, the State granted him a fund of 10,000 Kronen because of these studies. The question of rust which is also of the highest significance in Australia led in 1888 to the annual meeting of a Congress of Members of the Australian Colonies which, for a considerable number of years, published an official report, "Rust in wheat Conference."

In Germany, Sorauer's "Zeitschrift für Pflanzenkrankheiten" was followed in 1892 by C. v. Tubeuf's *Forstlich-naturwissenschaftliche Zeitschrift"* which devoted especial attention to plant diseases. In 1898 the"Kgl. bayrische Station für Pflanzenschutz" was founded with von Tubeuf as director. Besides this, reports in the collective work, "Just's botanischer Jahresbericht," published since 1873, became much more abundant, since a greater number of periodicals now included the subject of plant diseases in their programs. Among these belongs first of all the *"Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten"* issued by Uhlworm and Hansen, as also *"Hedwigia,"* edited by Hieronymous and P. Hennings, the *"Botanische Centralblatt,"* elaborated by Lotsy, also Biedermann's *"Centralblatt für Agriculturchemie,"* edited by Kellner, the *"Naturwissenschaftliche Zeitschift für Land-und Forstwirtschaft"* by von Tubeuf and L. Hiltner and the *"Practische Blätter für Pflanzenbau und Pflanzenschutz"* by L. Hiltner. We find thorough reports, especially on tropical cultivated plants, in *"Tropenpflanzer,"* Zeitschrift f. tropische Landwirtschaft, by O. Warburg and F. Wohltmann as well as in its "Beiheften" (supplements) which form the organ of the "Kolonialwirtschaftliches Komitee zu Berlin." In the German East-African colonies, Zimmermann is especially active in pathological fields as is shown by his *"Mitteilungen aus dem biologisch-landwirtschaftlichen Institute Amani."* In Austria the *"Zeitschrift für das Landwirtschaftliche Versuchswesen in Oesterreich"* was founded in 1898. In the following year P. Nypels began a series of publications under the title "Maladies des plantes cultivées" Bruxelles. In 1900, v. Istvánffi published the first volume of the "Annales de l'Institute Central ampélologique Royal Hongrois" as the report of the Central Vineyard Institute which had been placed under his direction. Here also especial attention was paid to diseases. The same is true also of the "Jahresberichte der Kgl. Lehranstalt für Obst-,Wein-und Gartenbau" published by Göthe and later by Wortmann in Geisenheim a. Rh. and the annual reports of the "Deutsch-schweizerische Versuchsstation für Obst-Wein-und Gartenbau zu Wädensweil," Zürich, revised by Müller-Thurgau.

This list of periodicals which in part review German and foreign literature and in part publish original articles, gives an insight into the unusually rapid growth of material which necessarily demands a unified summary in some collective work. Hollrung devoted himself to the working out of such a summary and since 1899 has been publishing a "Jahresbericht über die Neuerungen und Leistungen auf dem Gebiete der Pflanzenkrankheiten," Berlin, publishing house of Paul Parey.

Thus the new science of phytopathology has taken to itself the same literary methods which the older branches of knowledge use and which are undisputably necessary for scientific progress. But the practical side of phytopathology, viz., the protection of plants, has also found a desired development. The idea of establishing special institutions, suggested in 1880 by Korn, actively advocated in 1889 by Kühn and further developed by Sorauer at the International Agricultural Congresses and in the "Zeitschrift für Pflanzenkrankheiten" was brought in 1891 to general attention in the Prussian Abgeordnetenhause (Chamber of Deputies) by Schultz-Lupitz in the form of a motion. On the 27th day of April of the same year the "Reichsanzeiger" gave out that the motion of Schultz-Lupitz had been referred to the Royal State Administration for discussion and at once the Department of Agriculture attempted to test the question in how far the production of plants could be advanced by the enlargement of the scientific institutions subordinate to that purpose. As the question received a more thorough consideration, it became evident that the best interests of the protection of plants could only be had from an Imperial Institution. Such was now formed in connection with the Imperial Board of Health as a "Biologische Abteilung für Land-und Forstwirtschaft" and since 1905 this has been an independent institution of the Empire. The department, at present under Aderhold's direction, possesses in Dahlem, besides the proper laboratories, a very expensive experimental field and has published its results at indefinite intervals since 1900. Besides these scientific works the "Biological Division" also publishes popular bulletins and colored posters and in this way promotes the knowledge of the most abundant animal and vegetable agencies injurious to plants. Information as to their control is also distributed gratis, directly to these workers.

Besides the above mentioned imperial institution which now bears the title, *"Kais. Biologische Anstalt für Land-und Fortswirtschaft,"* we find in the different German States many organizations for the furtherance of plant protection, which in part are associated with the already existing high schools and experiment stations and in part are independent establishments. Among these, besides the institutions already mentioned at Halle and Geisenheim, there should be named also the *Anstalt für Pflanzenschutz* in Hohenheim, founded in 1902 and now under the direction of Kirchner.

We also find in the other European countries an active development of the study of plant diseases, proved by the publications of many institutions. Among these belong the "Bulletin de la Station Agronomique de l'Etat à Gembloux," Bruxelles (Em. Marchal), and "Travaux de la Station de pathologie végétale," by Delacroix, Paris, the "Tijdschrift over Plantenziehten" (Ritzema Bos) already mentioned and the "Landbouwkundig Tijdschrift," the "Oversigt over Landbrugsplanternes Sygdomme" Kjöbenhavn, in the "Tijdsskrift for Landbrugets Planteavl," Kjöbenhavn (Rostrup), the "Uppsatser i praktisk Entomologi," Stockholm (Lampa). "Beretning om Skadeinsekter og Plantesygdomme," Kristiania (Schöyen). "Berättelse öfver skäd-

einsekters uppträdande i Finland" (E. Reuter), in the "Landbruksstyrelsens meddelanden," Helsingfors, the "Annual report of the consulting botanist" (Carruthers) in the "Journ. Royal Agric. Soc.," London.

It is a matter of fact that countries outside of Europe have not been backward in the endeavor to increase plant protection. This branch of knowledge has been most advanced in North America where the Department of Agriculture at Washington has devoted special attention as well to animal enemies. Besides establishing the "Division of Entomology" which, by its valuable investigations, contributes essentially to the knowledge of animal injuries, the organization of meetings of agricultural zoologists is especially noteworthy. In these meetings questions of general significance are discussed. Besides this, many investigators in the Universities and Experiment Stations are working along these lines with gratifying results. Of the latter, we will mention the Agricultural Experiment Station of the State of New York at Ithaca and the New Jersey Agricultural College Experiment Station. Further statements are made in our detailed exposition in which the different bulletins of the institutions for the advance of plant protection are mentioned.

Besides the numerous publications of the United States of North America, the magazines of other countries also furnish noteworthy contributions to the knowledge of the diseases of cultivated tropical plants. Among them belong the "Mededeelingen van het Proefstation voor Suikerriet in West Java," the reports of the "Proefstation voor Cacao to Salatiga," Malang, the "Boletim da Agricultura," S. Paulo, "Boletim del Instituto Fisico-Geographico de Costa Rica," "Queensland Agricultural Journal," "Australian fungi" (McAlpine), in the "Proceed. Linnean Society of New South Wales," "Administration Reports, Royal Botanical Gardens," Ceylon, "Report of the Department of Land Records and Agriculture," Madras, and "The Journal of the College of Science, Imperial University of Tokio," Japan. We must refer to the "Botaniker-Adressbuch" by J. Dörfler, Vienna, 1902, for the numerous other institutions and individaul investigators.

APPENDIX.

In the above statements we have mentioned not only the literature on the subject but also given expression to the leading ideas of the different periods in order to show how the science has gradually developed to its present standpoint. To be sure, changes in the points of view on the nature and rôle of parasitic organisms are not without interest, but no less interesting are the references of the various authors to the influence of the stars, i. e. the atmospheric factors, which may be traced as a red line through all the reports. On this account we have often restated at length the earlier points of view and find a striking agreement with the oldest periods since emphasis is always laid on the dependence upon climatic and soil conditions and in part

also upon cultural habits of those phenomena, which we have learned to recognize as parasitic.

This idea, which is also the guiding principle in the present book, has led the author to undertake the first experiments for collecting the *Statistics of Plant Diseases*. These experiments which, as already mentioned, were begun with the help of the German Agricultural Society and continued by its "Special Commission for Plant Protection," have now found recognition, for the "Kais. Biologische Anstalt für Land- und Fortswirtschaft" beginning with 1905 has assumed the collection of statistics of plant diseases.

Doubt is often expressed as to the importance of such statistics for our subject and reference made to the fact that our most dangerous diseases are constantly present and the statements of the statisticians concerning the intensity of the attack and the amount of agricultural loss appear to be influenced so individually that all certain positive figures can never be attained. In opposition, it should be emphasized that I did not undertake the collection of statistics in order to obtain precise figures as to the distribution and agricultural effect of the different diseases. (Besides, in this connection, the making of reports will gradually, with the increased education of the body of observers, become as exact as it is in all provinces of organic life). The chief undertaking in the collection of statistics lies in the proof of the relations which the different diseases bear to climatic and soil conditions felt locally or universally, as well as to cultural factors. The study of the extreme forms of disease, easily verified, and the determination as to which factors have produced these extreme forms makes up the productive field of the statistics.

In these studies lies the future of pathology.

However valuable in themselves the observations as to the formal position and the life requirements of the parasitic micro-organisms may be, nevertheless, they form only one link in the chain of investigations and become important only in the determination of their *relation in nature and in the usual practice of agriculture*. And this we can recognize by means of a carefully arranged statistical office showing the conditions governing the increase or decrease of diseases.

This knowledge leads to the prevention of diseases by means of an ever-developing *plant hygiene* and plant pathology must develop further in this direction in the future.

DETAILED EXPOSITION.

SECTION I.

DISEASES DUE TO UNFAVORABLE SOIL CONDITIONS.

CHAPTER I.

THE LOCATION OF THE SOIL.

Even if the diseases which are due to an unfavorable location of cultivated land are better understood by means of the different factors because of which this position becomes injurious to plant growth, we have still considered it necessary to describe in the following section the general conditions due to different locations. We have done so because it is of special importance to the guiding principle of this manual and to any reference to a predisposition to certain diseases which is developed from this location of the soil that it be shown how the material and formal structure of any plant species changes with the condtions of the habitat, how thereby separate functions may sometimes be suppressed, sometimes advanced, and how accordingly the different localities impress their definite characteristics on the plants which, on this account, must behave very differently in relation to the different injurious causes.

1. ELEVATION ABOVE SEA LEVEL.

a. General Changes in Habitat in Relation to Herbaceous Plants.

There is no need of discussing further the fact that the temperature always falls with an increase in elevation of any cultivated surface above sea level and that this fall in temperature is a determining factor for limiting vegetation, on which account the time of harvest in mountains must always be later than on lower levels. It is an universally recognized fact that this later harvest brings with it great difficulties in curing the grain and not infrequently makes necessary special precautions in high mountains, and that despite these precautions there often takes place a blackening of the grain as a result of the beginning of fungous growth. An example with exact figures

is given by Angot[1], according to whose observations the harvest of winter rye in France is delayed on an average about four days, as the elevation increases about 100 meters. Attention should be called, however, to the circumstance that, with increasing height, the air being thinner is less warm so that therefore it must have an appreciable effect on the development of vegetation. With this should be reckoned conditions of moisture which, aside from the physical constitution of the soil, are different for plants of Alpine regions in lower latitudes than for those from plains in the Arctic zone. Within the same degree of latitude mountains, as colder bodies, will condense more water vapor and thereby bring about more abundant precipitation than takes place on plains. On this account more snow will fall and the warmth needed to melt this greater mass of snow is withdrawn from vegetation. Even after the snow has melted in spring, the plants in the mountains will nevertheless at first be less able to benefit from the sun's warmth than those on the plains since the inequalities of the upper surface of the soil become effective. A square meter of very broken ground surface has a much greater upper surface, divided into many slanting levels, over which the same amount of warmth must be distributed, than has perfectly level land, the different particles of which are raised to a higher temperature. This is the case in mountain chains in contrast to level plains. It is evident from these statements that with increased elevation above the sea these processes of weathering and decomposition must be retarded since they are essentially favored by warmth. It is also evident that such peculiar combinations of vegetative factors will produce characteristic forms, of which the best known feature is short, repressed growth. Such forms of growth are kept constant, first of all, in the seeds. Climatic forms which have become hereditary in this way have been termed *"Oecological variations"*[2].

If it was said at first that the temperature of the air at higher levels is lower, it must also be emphasized, on the other hand, that at higher levels the intensity of the illumination increases and produces accordingly greater *soil warmth*. On this account climate of the lower and middle latitudes, on account of the greater intensity of light and greater warmth of the soil, would differ favorably from that of those plains in a Polar zone where the temperature of the air is the same. The lesser atmospheric pressure in mountains must result in an increase of transpiration as stated by Friedal[3] and the increased supply of light in an increase of the assimilatory activity of the leaf. Consequently the typical mountain plant works more energetically and in this way is explained its shortened vegetative period.

According to the observations of Bonnier[4], who made experimental gardens on Mt. Blanc and in the Pyrenees, in Alpine climates with a

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[1] Der Naturforscher, 1883, No. 24.

[2] Lebensgeschichte der Blütenpflanzen Mitteleuropas. Von Kirchner, Loew und C. Schröter. Stuttgart, Ulmer 1904. p. 116.

[3] Friedal, Action de la pression totale sur l'assimilation chlorophyllienne. C. rend. 1901. Cit. Bot. Jahresb. 1901. Section II, p. 221.

[4] Bonnier, Etude expérimentale de l'influence du climat alpin sur la végétation etc. Bull. Soc. Bot. France. Vol. XXXV. 35. 1888.

greater number of herbaceous plants, the shoots became shorter, leading to nanism. In specimens from high mountains, the palisade parenchyma is more strongly developed and contains more chlorophyll. Accordingly, the assimilatory work has been increased. If the leaves of the same species from specimens grown on plains and in mountain gardens, are cut off at the same time and tested, the leaves from the high mountains showed a stronger development of oxygen in an equal length of time for equally large surfaces. It is said that such Alpine characteristics can be artificially bred in plants by packing them in ice at night while leaving them during the day under normal growing conditions[1].

In a later report, Bonnier[2] calls special attention to the increase in temperature and assimilation which, taking place in Alpine regions, may easily account for the fact that plants from the plains, brought into an Alpine climate, develop relatively greater amounts of sugar, starch, volatile oils, coloring matter, alkaloids and other products of chorophyll activity.

How greatly this specific climatic character immediately influences the mode of development of any plant species is shown by the well-known experiments on structure carried on from 1875 to 1880 by Kerner v. Marilaun[3] with seeds taken from the same parent plant which had been grown with precaution against cross-fertilization. Part of the seeds were sown in an Alpine experimental garden on the top of Mt. Blaser in the Tyrol (2195 m. elevation), others in the botanical garden in Vienna. The germination of the seed on top of Mt. Blaser took place soon after the melting of the snow which had been 1.5 m. deep, between the 10th and 25th of June. The germination and growth of the seedlings therefore took place when the sun was highest and the days longest. The seedlings were exposed at once to a temperature which was just as high or perhaps somewhat higher than that furnished the experimental plants in the botanical garden at Vienna, when the March day was twelve hours long. At the end of August and the beginning of September blossoms were observed on the plants which had not been killed by the several frosts in June, July and even in August, for example, on *Satureja hortensis, Lepidium sativum, Agrostemma Githago, Centaurea Cyanus, Turgenia latifolia etc.*

The plants grown in the Alpine experimental gardens differed from those in the botanical gardens at Vienna in that they were strikingly shorter and their stems developed a greater number of parts. It was found further that in the Alpine specimens, for instance, *Viola arvensis,* blossoms developed even from the axis of the third and fourth leaves while at Vienna they came only between the seventh and eighth leaves. The number of blossoms was fewer and the petals, like the leaves, were smaller, as a rule. A part of the

1 Palladin, Onfluence des changements des températures sur la respiration des plantes. Revue gén. de Botanique, 1899, p. 242.
2 Bonnier, Gaston, Influence des hautes altitudes sur les fonctions des végétaux. Compt. rend. de l'Acad. scienc. Paris. Vol. CXI. 1890. Cit. Bot. Centralbl, 1891. No. 12.
3 Pflanzenleben. Vol. II, pp. 453 ff. Wein. 1898.

annual species from the plains which had had sufficient time and warmth to develop seeds were longer lived on the top of Mt. Blaser since in the following year, new sprouts were developed from the lower part of the stems. An earlier blossoming could also be observed.

Corresponding to the fact that the intensity of the sunlight increases with increased elevation, the color of the blossom, depending upon the anthocyanin, also became more intense. Blossoms, which were white on the plains, had in the Alps petals which were violet underneath. The glumes of grasses, green on the plains, or only pale violet, became dark brownish violet in Alpine regions because of a more abundant formation of anthocyanin[1]. The leaves of *Sedum acre, S. album and S. hexangulare* became purplish red. On the other hand, leaves of *Orobus vernus, Valeriana Phu* and *Viola cucullata* turned yellow from the excess of light in the Alpine experimental gardens while in the valley in shaded places their foliage remains green.

The mountainous region affects not only temperatures in the annual seasonal average but especially the moisture content of the atmosphere. Warmth and humidity in their total amount and in their distribution during the seasons together with the supply of light are determinants of growth. As already mentioned, atmospheric moisture influences the amount of light available for the plant, for a humid atmosphere absorbs about five times as many light rays as does a dry atmosphere.

Since the absolute content of the air in water vapor decreases with the elevation, less light will be absorbed in the mountains, especially since the rays of light have a shorter distance to traverse in order to reach the earth as compared with regions at sea level. The fact that the absolute vapor content of the air decreases with the elevation is a matter of course for, since the temperature becomes lower and lower, the air must condense its water vapor and give it off in a liquid form. But the relative moisture increases in the mountains which explains why we call a mountain climate damp and rainy. Cloudiness is also relative to the moisture of the air.

This increase of the relative moisture and the decrease of temperature form the reasons for the rapid ending of our cultural efforts so far as these concern the obtaining of seeds in mountain regions. We know that the formation of blossoms and seed requires an increase of warmth proportionate to the length of the growth period. For this reason we find, as mentioned at the beginning, that grain often does not ripen in the mountains and that therefore clover and other legumes furnish an insufficient amount of seed. Yet another condition must be added to those already mentioned, to which Pax has called attention[2], viz., that the insects are only half as num-

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[1] The theory that anthocyanin is developed for the protection of the plant against too strong sunlight is held by many investigators. Kerner (l. c. Vol. I, p. 508) assumes that, in the reddening of blossoms which appears with a lack of heat, the loss to the blossoms of the directly conducted heat is compensated "by the heat obtained from the rays of light by means of the anthocyanin." We believe we have observed that the red coloring matter indeed does develop abundantly with a lack of heat, but can also set in with an abundance of heat if, in proportion to the heat, an excess of light makes itself felt in the tissues which contain sugar.

[2] Das Leben der Alpenflanzen. Zeitschr. d. d.-östr. Alpenvereins 1898, p. 61.

erous at an elevation of 2300 m. as on the plains. On this account labiate plants play a considerable rôle on high mountains. Also the increased difficulty of insect fertilization is partly equalized by the fact that an asexual reproduction also takes place *(Polygonum viviparum, Poa alpina, Saxifraga cernua)*; further, ten-elevenths of all kinds of small bushes and even *Viola tricolor*, an annual with us, become perennial in the Alps.

Besides this, reference should be made to the fact that, with unlimited cultural experiments at high elevations, short-lived mountain varieties are formed which, to be sure, furnish seed in smaller amounts but more satisfactory in quality. This offers greater possibilities of yielding a good harvest in the mountains and (according to Schiebler)[1] has the advantage of retaining at lower levels its shortened period of growth and therefore can be used advantageously in Northern climates.

Development of the Aerial Axis of Woody Plants.

In contradiction to a widespread opinion, it should be mentioned, that *dwarf growth* in high mountains is not to be ascribed to the pressure of the snow since we have tree-like forms in those regions where the most snow falls. It is known that the *snow covering* does not become thicker, the greater the elevation of the mountain, but with us increases up to perhaps an elevation of 2500 m., that is, only to the upper boundary of the dwarf conifers, dwarf alders and the Alpine rose. Higher up the amount of precipitation decreases. Spruces, larches and the cembra-pine suffer less from snow pressure when they stand alone or scattered because their elastic, sloping older branches let the accumulated snow slip off more easily when the wind blows. Other trees, like *Salix serpyllifolia and Rhamnus pumila*, frequently escape excessive snow pressure by their growth on steep rocky cliffs from which the snow slides rapidly. However, trees exposed to the full pressure of the snow can scarcely be made to grow *closer to the earth* because of the burden of the snow or of windy weather. Rather, we may assume with Kerner that it is the soil warmth which, in the immediate proximity of the earth, affords them the best conditions for existence. In the higher Alpine regions the soil is much warmer than the air which absorbs less sunlight on account of its increasing thinness and its rapidly decreasing water content. The above quoted author cites that, for example, on the top of Mt. Blanc (4810 m.) the intensity of the sunlight is 26 per cent. greater than at the level of Paris. On the Pic du Midi (2877 m.) a temperature of 33.8°C. was observed in the soil on which the sun shone while the air showed a temperature of only 10.1°C. This warmth of the soil together with the intensity of the light explains the speedier development and blooming of Alpine plants.

Vöchting[2], in opposition to Kerner, thinks, on the ground of his observations with *Mimulus Tilingii*, the young branches of which at a defi-

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[1] Schiebler, Die Pflanzenwelt Norwegens. Allg. Teil. Christiania 1873.

[2] Vöchting, H., Ueber den Einflufs niedriger Temperatur auf die Sprofsrichtung. Ber. Deutsch. Bot. Ges. XVI. 1898, p. 37.

nite age incline downward in spring when the temperature is lower and straighten up later with increased warmth, that the creeping habit of growth of Alpine plants may be ascribed in part or entirely to the influence of the low temperature. We can not agree with this theory.

Rosenthal[1] made investigations concerning the mode of growth of trees in Alpine regions. He found that in all the species of wood studied the annual ring is narrower in high countains than in the lowlands. The eccentricity of the branches is usually very great but the direction of the greatest increase of growth varies. The vascular system, on account of the increased evaporation, is more extensively developed. In dicotyledons, a higher percentage of the vascular tissue is obtained by a narrower annual ring; in conifers there is a considerable decrease of the late wood ring.

The landslides which continually take place in mountains because of storm conditions displace the trees and thereby change their woody development. Hartig[2] pointed out the formation of broad annual rings and so-called "red wood" (wood with short tracheids and strong lignification) on the underside of the trunks and branches of the spruce as soon as they bend toward the horizontal, while slender annual rings and "strain wood" (long tracheids with weak lignification) are formed on the upper side. According to Giovanozzi[3] this difference in the formation of the wood ring of conifers is made use of in hygrometric measurements by the inhabitants of the Piedmontese Alps since the small celled, thin-walled red wood possesses hygroscopic characteristics very different from those of the strain wood. The red wood side of a peeled branch becomes concave in dry air, convex in moist air.

According to the investigations of Cieslar[4] the lignin content of spruce wood seems to be less near the upper boundaries of the tree zone than in lower positions.

It will be concluded from Cieslar's[5] observations, that the suppressed growth in Alpine forms is hereditary for the immediately following generation, according to which spruces from seeds of trees grown in mountainous regions grow more slowly when cultivated on the plains than do plants raised from seeds of trees from the plains similarly grown. Engler has made the same observation in seeding experiments at the forestry experimental station in Zürich. From germination experiments with the seeds of spruce, pine and other forest trees, M. Kienitz[6] concludes that the minimum, optimum and maximum germinating temperatures of spruce seed indigenous to lower regions are higher than for seeds grown in higher positions.

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1 Rosenthal, M. Ueber die Ausbildung der Jahresringe an der Grenze des Baumwuchses in den Alpen. Dissert. Berlin. cit. Bot. Centralbl. 1904. No. 43.

2 Hartig, R., Holzuntersuchungen. Berlin. Springer 1901.

3 Giovanozzi, Sul movimento igroscopico dei rami delle Conifere. Malpighia XV, cit. Bot. Jahresb. 1901. Sec. II, p. 191.

4 Cieslar, A., Ueber den Ligningehalt einiger Nadelhölzer. Mitt. a. d. Forstl. Versuchswesen Oesterreichs 1897. Part XXIII.

5 Centralbl. f. d. gesamte Forstwesen, 1894. Vol. 20, p. 145.

6 Kienitz, Vergleichende Keimversuche mit Waldbaumsamen aus klimatisch verschieden gelegenen Orten Mitteleuropas, Ref. Bot. Zeit. 1879. p. 597.

In plantations in high altitudes, however, it must further be taken into consideration that the elevation acts differently according as it presents isolated peaks or high plateaux. Since the earth's illumination and radiation have considerable influence on the temperature of the layers of air covering it, vegetation at equal heights is exposed to very diverse temperature fluctuations. On the high plateau the decrease of warmth with elevation is less, when the sun shines, than on the mountain peak which stands alone. If, however, the sun disappears and radiation becomes determinative, then the lower air layers above the high plateau also cool off more. Thus the daily fluctuations in temperature are much greater here and the seasonal ones as well. On high plateaux the temperature can fall, even to frost, while the isolated peaks remain protected. The same relation is shown between valley and heights; we have recently observed a number of examples from Italy. Passerini makes[1] the following observations from the neighborhood of Florence and cites, as an especially good instance, the night of April 19-20, 1903, when the temperature, which on the 15th still showed +18.3°C. sank to —1.1°C. and rose again, nine hours later, to +12.2°C. While the vegetables and grains were not injured, the leaves and blossoms were seriously frozen. Only 50 m. higher the injuries were no longer noticeable.

In mountainous regions clouds and *mist* act as a protection from frosts. Thomas[2] observed in Thüringen that the young beech foliage did not suffer from frost at heights covered by mists while in the valleys and gorges the leaves were injured. The artificial prevention of frost by the production of smoke has been founded on the peculiarity of mists which prevents the sharp fall in temperature.

Adjustment of the Root Body of Woody Plants.

In mountains the adaptation of the wood body to the rocky soil and the compensatory structures which appear on this account are especially interesting. In the following figure 1, we see the root of an oak which has made its way through a fissure in a rock and by its continued growth in thickness within the split has developed into a flattened, board-like form. After leaving the rock, the root resumed its cylindrical form. This example shows first that, despite the pressure which the strong root had withstood for so many years, the ability to conduct water and plastic material has not been interrupted in the board-like part. In the second place, we notice above the board-like flattening the appearance of adventitious roots. Both processes correspond to the phenomena caused by artificial constriction.

So far as we have been able to investigate roots which had been flattened in the clefts of rocks, we could observe that the board-like flat places in the root body were produced because the wood rings formed every year were very strongly developed on the sides where they could develop freely,

[1] Passerini, Sui danni prodotti alle piante del ghiacciato etc. Bull. Soc. Bot. ital. 1903. p. 308.

[2] Thomas, Fr., Scharfe Horizontalgrenze der Frostwirkung an Buchen. Thür. Monatsblätter. April 1904.

therefore, in the direction of the split surface, but, on the other hand, they were reduced to a minimum on the side where the roots were pressed against the rock and were finally irrecognizable. On the free side of the wood the vascular bundles developed very abundantly, in some annual rings, in fact, the wood was very broad and provided with a thick bark; on the side of the root pressed against the rock, the wood lacked all vascular formation, was short-celled and formed from wood fibres inclined diagonally instead of

Fig. 1. Fig. 2.

Roots of Quercus Pedunculata grown between rocks. (After Döbner-Nobbe.)

running vertically. Finally, differentiation into annual rings could not be observed and only a very slender cork layer is seen lying on the occasionally formed short-celled parenchyma, without any recognizable differentiation into medullary rays.

Nevertheless, the cambial activity was not lost in the board-like part of the root as was evident when the pressure ceased, for the flattened part grew normally in its cylindrical form. Anatomical changes in the roots pressed between the rocks approximate so strikingly the results obtained by artificial

constriction of the aerial axis, that we can refer in this connection to our subsequent studies in the chapter on "Wounds."

Figure 2 shows a different root, also from *Quercus pedunculata,* which probably has only been pressed between stones. In meeting with this obstruction to its growth in length it was bent and, when growing further, became flattened. With increasing age the pressed root surface again reached the open and with the removal of the pressure came an increased formation of the wood ring in great luxuriance like callus rolls. The squeezing which the roots had undergone, might have acted like girdling and have produced in this a kind of girdling roll above the place of pressure. (See Girdling in the chapter on "Wounds").

We can get an idea as to the anatomical conditions in the first stages of such flattening of the root from the investigations of Lopriore[1]. He observed adventitious roots in the germinating plants of *Vicia Faba* which were forced to grow under the lateral pressure of cotyledons which had not separated from each other. Within the sphere of pressure these tender roots appeared flattened like ribbons but after leaving the region of pressure, they again became normally cylindrical just as was noticed in the oak roots. In the very young roots of the horse bean *(Vicia Faba)* Lopriore found that the epidermal cells on the sides not pressed upon by the cotyledons had developed into root hairs. On the compressd sides, however, not only the epidermal cells were tangentially flattened but also the two or four outer layers of the bark were considerably pressed so that they formed a kind of peripheral girdle around the root on these sides, whereby the radial walls of these compressed cells seem folded zigzag as in a bellows. The cells subjected to the pressure of the cotyledons were 'also proved changed materially since their membranes either developed into cork or "together with their lumina were impregnated with a kind of protective gum."

We have already called attention to the fact that in figure 1 several adventitious roots had been formed above the board-like flattening. As may be seen, the root had made a curve here before entering into the split in the rock and under the influence of this twisting, a new formation of adventitious roots had been started on the free convex side. We perceive in this a result of the stimulus of twisting which Noll[2] has discussed in detail in his work. It is easy to observe that roots which have become twisted because of a pressure, hindering their growth in length, develop new side roots on the convex side at the point of twisting. In water cultures in glass vessels this phenomenon may be observed when strong roots reach the bottom of the vessel and grow against it.

In mountains emergency precautions are met with in the flatly growing, younger tree roots if the tip of a rootlet has been lost through injury or from

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1 Lopriore, G., Verbänderung infolge des Köpfens. Ber. Deutsch. Bot. Ges. Vol. XXII, Part 5, p. 309.
2 Noll, Vergleichende Kulturversuche. Sitzungsber. d. Niederrhein. Ges. f. Naturkunde. Cit. Bot. Jahresber. 1900. II. p. 304.

drying out on the rock. In figure 3*a*, we see such a compensatory root which has been developed above the dead tip of the main root *AA*. The compensatory organ is much stronger and fleshier than the side roots which had been formed earlier.

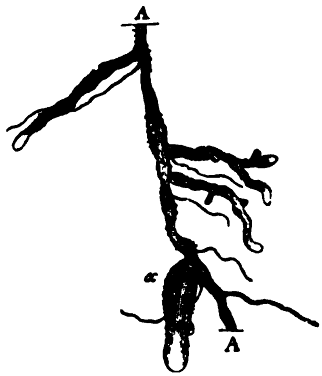

Fig. 3. Branch of a spruce root on which a fleshy compensatory root has been formed above the dead tip. (After Nobbe.)

The formation of adventitious roots as a result of the stimulus of twisting or of injury to the root is constantly utilized technically in the cultivation of trees. In tranplanting seedlings of forest or fruit trees the main root is either twisted spirally in the hole where it is to be planted or it is shortened about a third. A stronger cutting back is not advisable because adventitious roots always develop more weakly the older the parts of the axis which are twisted or cut back.

b. Special Cases of Disease.

Retrogression in the Cultivation of the Larch.

As a striking example of the disadvantages developed by the cultivation of plants from mountain climates when grown on the plains, we might consider the often noticed retrogression in larch plantations. Kirchner[1] mentions, when describing the life history of this forest tree, that it is a true high mountain tree of the European Alpine and Carpathian systems. The natural area of its distribution extends from Dauphiné through Switzerland, past Vorarlberg, the Bavarian and Salzburger Alps to the Moravian-Silician depression, and to the Carpathians, up to the hilly country of Southern Poland. The upper limit for the larch is about 2400 m., the lower one in the Alps 423 m., in the Sicilian mountains about 357 m. While it thrives in Scotland, Sweden and Norway, it does not grow very well in Middle and Northern Germany or in France. When growing together the spruce usually forces out the larch except in the highest altitudes. When the spruce grows on dry soil it is shorter than the larch. Of all the indigenous conifers the larch needs the most light. It exceeds all conifers and most deciduous trees in its transpiration. Because it is not sensitive to cold, as shown by its natural habitat, it is much more dependent upon the warmth of the summer to make its best growth. It lives in regions where the summer is constantly and uniformly warm, where there is abundant circulation of air and a winter's rest of at least four months with a short spring and a rapid transition from spring to summer. Because its leaves come out extremely early, it makes the most of the very short period of growth.

These statements are based on the observations of numerous specialists and may on this account be acknowledged to be thoroughly reliable. We ob-

[1] Lebensgeschichte der Blütenpflanzen Mitteleuropas. Vol. I. Part 2. p. 157. Stuttgart, Ulmer 1904.

tain an insight into its material composition from the works of Weber[1]. He studied sections of the trunk and the needles of the larch picked in October in the Bavarian Alps, in the Spessart, from the plains of the valley of the Main etc. In spite of the soil differences, the results agreed entirely in regard to the influence of elevation. Weber summarizes these as follows:

The organic substance of the needles increases with noteworthy regularity with the absolute elevation of the habitat while the content in pure ash decreases. The amount of ash becomes absolutely greater if the larch grows on the plains or in moderately high mountains *so that therefore to produce an equal amount of burnable substance, more and more minerals are taken up by the plant, as its cultivation descends into the plains.* The most important elements of the ash, potassium and phosphoric acids, show a regular increase in specimens from the plains in contrast to Alpine Larches. In regard to the calcium content, the larch of the plains indeed excels, yet the constitution of the soil seems to be very determinative here; magnesia and sulphuric acid show an insignificant increase, while ferric oxid and silicic acid show a considerable increase.

It may be perceived from Weber's investigations how very greatly the life habits of this high mountain tree and its mineral composition change with its descent to the plains and the question now becomes pertinent as to whether the anatomical structure is not also changed by the entirely different conditions of life on the plains. Primarily the plains offer strong contrasts from the most intense heat of summer to the great cold of winter. To this must be added a lengthened spring with the summer-like days which sometimes begin in February, always in March, and the subsequent relapses to cold weather. However, the autumns of the plains may be of decisive significance when a relatively warm, damp period not infrequently lasts into December and does not permit the cessation of vegetation. One needs think here only of our oaks and apple trees which often enough retain their foliage on the tips of the branches throughout the whole winter. In apple trees, especially in trellis and trained forms, many varieties did not develop any terminal bud in autumn but the last leaf simply remains in the winter in an unformed stage of development.

In the larch these long, wet and relatively warm autumns stimulate growth so that after the normal summer end of the annual ring, a few layers of spring wood are formed, as I have often observed. Therefore in such cases on the plains the beginning of an absolute dormant period (which Kirchner emphasizes as necessary for the normal development of the larch) does not take place and the immediate results will frequently be the loss of the normal or usual resistance to frost. The frost wounds make possible the entrance for all wound parasites which, in the often dense growth of larches on the plains and the moist motionless air, find the most favorable environ-

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[1] Weber, R., Einflufs des Standortes auf die Zusammensetzung der Asche von Lärchen. Allgem. Forst-u. Jagdzeitung 1873, p. 368 und in Biedermanns Centralbl. f. Agriculturchemie, 1875, p. 336.

ments for their growth and distribution. For this reason the fungus of the so-called larch canker, the *Dasyscypha (Peziza) Willkommii,* is so abundant in old larch plantations and the trunks of the young copse wood are covered with lichens.

The complaint that the trees in northwest and middle Germany and in France, on an average, show no satisfactory growth is explained by these conditions of growth on the plains diametrically opposed to the nature of the tree. This is also the reason for the reaction which has taken place in the usual enthusiasm of foresters for the cultivation of the larch.

The comprehension of our mistakes in growing the larch and the intenability of the widespread assumption that it can be grown in any place has recently been gathering force in forestry circles. A little paper published by the First Commissioner of Woods and Forests in Hameln[1] is of the greatest significance. He observed that the larch canker occurs only where the tree is grown under hindering conditions or is crowded by its neighbors. The point which he makes strongly is "that the sun is the nurse of the larch." Complete agreement with this discovery has come from an extensive inquiry on the part of the English Dendrological Society contained in Sommerville's reports[2]. From this report canker seems to be increasing in England on the larch and attacks trees from seven to fifteen years old most easily. Dampness in dense growths favors the disease which occurs less often on altitudes than in hollows. Many practical foresters maintain that the disease is inherited through the seed; and, while Sommerville does not share this point of view, he cannot disprove the assumption of an ***hereditary predisposition***. Also the assertion that nurseries spread the disease may not be repudiated entirely.

We completely understand such statements also heard frequently in Germany. Such predisposition to sickness lies in the changed mode of growth which is a result of the removal of the tree from mountains to plains, thus destroying its natural immunity. It is reasonable that nurseries with their rapid forcing of the seedlings in manured soils, excusable because of agricultural reasons, increase this weakening of the larch. We find similar conditions also for other conifers; for example, we have examined pine seedlings from nurseries and forestry seed-beds which had begun to suffer from leaf cast, and we have always been able to prove that the beginning of resinosis was present even in the first annual ring.

Weber[1] observed in beech foliage conditions similar to the larch in regard to the difference in the ash content. From investigations from eleven different habitats it was found that the percentage of ash in beech

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1 Die Lärche, ihr leichter und sicherer Anbau in Mittel-und Norddeutschland durch die erfolgreiche Bekämpfung des Lärchenkrebses. Leipzig 1899.

2 Report by Dr. Sommerville on the inquiry conducted by the Society into the disease of the larch. Transact. of the English Arboricultural Society. Vol. III, Part IV. 1893-94.

3 Weber, Einflufs des Standorts auf den Aschengehalt des Buchenlaubes. Allg. Forst.-u. Jagdzeitung, 1875, p. 221, cit. in Beidermann's Centralbl. f. Agrikulturchemie, 1875, II, p. 325. The percentage of ash content and especially of calcium and silicic acid becomes greater the more slowly the plants grow.

foliage from altitudes over 1000 m. above sea level was noticeably less than in that from lower levels. The latter showed, however, in its ash, a smaller amount of potassium, phosphoric acid and sulphuric acid, while the leaves collected in altitudes were proved to be as rich in these substances as the young foliage. The distribution of calcium and silicic acid was the opposite. The size and weight of the average leaves decrease with the elevation. In regard to morphological changes, H. Hoffman[1] states that the young sprouts of *Salix herbacea* and *S. reticulata* transplanted from high mountains to low levels grow erect instead of lying flat on the soil. When moved from lowlands to high mountains, *Solidago Virga aurea* becomes an aenemic dwarf. *Plantaga alpina* is a meagre mountain form of *Pl. maritima* not coming true to seed and with short ears. The length of the ears increased in the second generation on the lowland from 15 to 18 mm.; the leaves became broader and even serated; there were fewer blossoms at this altitude but not smaller. *Hieraciun alpinum* developed on the lowland isolated specimens with tall, much branched stems. *Aster alpinus* in isolated examples developed broader leaves. *Gnaphalium Leontopodium*, the Edelweiss, loses on the plains its little inflorescences and pubescence.

The facts ascertained when the larch was brought from the mountains to the plains seem to be a very sharp warning to consider more carefully the natural requirements of the trees and not to believe, because possibly supported by soil analysis, that each tree must thrive where nutritive substances are abundantly present for it. The great physical conditions, such as ventilation, illumination and dampness, are determinative factors which, taken under due consideration, preserve the natural immunity of the tree and make superfluous a petty local combatting of the parasites.

Lack of Success with Tropical Plantations.

Like every nation at the beginning of its colonizing period, we must recognize that great loses occur in newly organized tropical plantations. An essential factor for the protection from agricultural injury is to be found, we believe, in the insignificant consideration of the native conditions of growth from which the tropical useful plants originate. In regard to the transplanting of plants from the plains into an altitude, the increase in the relative dampness is of especial importance, next to the decrease in temperature. These conditions, for example, quickly place a limit for the cultivation of grain. According to Fesca's reports (l. c. p. 42) grain species do not flourish at all in the lower regions of the tropics and the ripening of the grain becomes uncertain in the higher regions. In Java and Ceylon, cultivation of our species of grains and Leguminoseae with a view to raising seeds becomes doubtful, even at elevations of scarcely 2000 m.

On the other hand a smaller difference between the temperatures of winter and summer is of great value, especially to tropical plants. Many plants

[1] Rückblick auf meine Variationsversuche, Bot. Z. 1881, p. 431.

for which the plains are too warm, thrive better in the more uniform climate of the higher altitudes. Thus Fesca[1] mentions that cocoa thrives best at an elevation of about 500 m., Arabian Coffee from 600 to 1200 m., and more, and tea from 1000 to 2000 m. For sugar cane, however, places are necessary in which occur periods of high temperature. Accordingly the cultivation of sugar cane on the sub-tropical plains often reaches even to the 35 parallel of latitude, in Mediterranean regions to the 36 parallel of latitude where the heat temperature for two to three summer months rises above 25°C. The cultivation of sugar cane for factories, however, even in narrow tropical zones is seldom successful higher than 300 m. Indeed it is planted higher up but then only used for the purposes of propagation because of the rapid decrease in the sugar content. At such heights, however, the cane escapes the *"sereh disease"* so much feared at present and on this account it has been proposed that the plantations for the sugar be regenerated by making propagating fields with the proper cultural varieties at high elevations and using as stock the material from these for cultivation on the plains.

In other tropical plants the uniformity of the climate is not the decisive factor but the high summer temperatures necessary for the maturing of the fruit. Thus in the narrower tropical zone cocoa palms are found at an altitude of 1000 m. but fruit is rarely produced at an elevation of 900 m. In the same way Fesca cites the grape fruit which endures cooler winter temperatures but requires a high summer temperature to mature its fruit. On this account its fruit will ripen in Japan between 31 and 32 degrees latitude with an annual mean temperature of 16.5°C. while in Bandoeng on Java at an elevation of 714 m. and an annual temperature of 22.7°C. no fruit ripens. In Japan during the months of July and August the temperature is high enough to ripen the fruit when the monthly mean temperature exceeds 26°C. and even in September is more than 24°C. Such temperatures, however, are not found in Bandoeng.

Tea is cultivated advantageously in mountain environments. The tea plant loves abundant moisture, hence is naturally a sub-tropical plant. Taking advantage of the climate of high elevations, it can be grown successfully in the tropics. Thus it is found on Java and Ceylon and in India up to an elevation of 2000 m.; the highest plantations in the Himalayas often lie at about 2200 m. Tea from the higher localities is in fact more highly prized. To be sure, greater quantities of leaves are harvested on tropical plains but the quality of the leaves is poorer.

It is a mistake to attempt the cultivation of coffee on plains without other shade. Coffee is a tropical plant from high elevations demanding uniformity of climate. The failure of the crops on the plains may often be traced to the great fluctuations in temperature and moisture much more noticeable there the less the care taken for shading. In the sub-tropical zone

[1] Der Pflanzenbau in den Tropen und Subtropen von Prof. Dr. Fesca. Vol. I., Berlin, Süfserott, 1904., p. 41.

the summer temperature rises so high and the winter temperature falls so low that growth, which normally should be continued uninterruptedly, ceases for the time being.

Cocoa, however, to a more marked degree, requires a uniform high amount of moisture in the air and soil together with shade and protection from the wind;—it can scarcely ever become too warm for cocoa. Where it is cultivated, i. e. the narrower tropical zone up to an altitude of 500 m., it developes numerous forms but in all ecological varieties, the same requirements are felt as to the climate. Fesca (l. c. p. 240) recommends the consideration of its need of shade especially when the plantations are young. Zehntner[1] describes a disease affecting these plantations. It appears in the form of brown specks on the bark of two or three year-old saplings. After transplantation, the little trunks are more exposed to the wind and the sun and the bark cracks open in different places.

2. SLOPE OF THE SURFACE OF THE SOIL.

The slope of the surface becomes a factor which must be considered when the local changes due to the influence of the geographical position are studied. Inclinations of from 1° to 10° and at the most 15° are the most important, for greater inclinations are less suitable for fields. Noll[2] has reported an advantageous result of the inclination of the soil. His experiments showed that, on rolling land artificially made, an increase of the cultural surface is obtained which in growing lettuce increases the yield about 31 per cent. But even a slight inclination has disadvantages since rainstorms gradually carry off the friable earth leaving the sub-soil behind.

The point of the compass toward which the cultural land slopes is also very important. Southerly or southeastern slopes are most subject to disaster because of the great weather changes. The higher temperature prevailing here forces the growth rapidly in spring; in summer the danger of drying is greater, for the soil is exposed not only to the south winds but also to the dry east and southeast winds and anyway to the cool, damp west winds, but is protected from the north wind. Since, however, dry winds prevail during the spring, i. e. the important vegetative period, the southern declivities dry out very especially and consequently in mountains the southern side is replanted with great difficulty, hence is usually bare.

The advantages of the southern exposure are most marked in short cool summers. Because of this declivity short lived plants will often mature their fruit only in such positions; hence these slopes are best used for the cultivation of such plants as are grown on account of their fruits and needing the increased action of warmth and light. A colder exposure, however, would be used to better advantage for such plants as are utilized for foliage and wood.

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1 Proefstation voor Cacao te Salatiga. Bull. 4.
2 Noll, Vergleichende Kulturversuche. Cit. Bot. Jahresb. 1900. II, p. 304.

When cultivating monocarpic plants, such as vegetables, the injury due to an otherwise suitable exposure, viz., injury from spring frosts, is felt only when the small plants are put out early in spring. There is still greater injury to sensitive polycarpic plants to which our nut trees belong. Here, with a favorable, warm exposure, there is a failure of the harvest, while in the same year nuts are produced abundantly with raw exposures. In the first case the young shoots and blossom buds, forced out earlier by the greater warmth, are blasted by the night frosts which have not harmed the less developed specimens found in high raw exposures.

In garden plantations, when taking advantage of such positions, one attempts to avoid the disadvantages of the spring frosts by holding the plants back artificially. This is done by leaving them covered longer, either by heaping snow on them or by increasing the mats and litter. With fruit trees snow, ice and mulching are heaped about the base in order to keep the soil cool as long as possible and thus retard the root activity.

The cold northern exposure is best for meadows and forests. Eastern slopes are unsuitable if the soil is sandy because they dry out more quickly. They are therefore more valuable if the soil is heavy. The reverse is true of the damp westerly side. Holzner[1], comparing a slope at 50° north latitude, inclined about 10° southerly, with another with a 10° northerly inclination, also took into account the difference in warmth which can be called forth by an inclination of 10°, when all other condtions are assumed to be equal. The sum total of the sun's rays falling upon this soil bears the proportion on the south and the north slopes of approximately three to two.

Wollny's[2] experiments on the warming of field lands deserve especial mention. In this work Kerner's[3] observations are cited, showing how differently the several sides of a hill warm up. These observations follow closely upon the preceding ones. The mean found by three years of observation showed that the exposures may be arranged as follows, decreasing according to their warmth. The warmest exposure was S. W. then followed S., S.E., W., E., N.E., N.W. and N. This scale shows that in reality the different exposures do not act as one would first suppose theoretically. It would seem first of all that with the sun equally high above the meridian the heating would be equally strong and that, therefore, the southeast side would receive the same amount of warmth as the southwest side. Kerner explains that this is not actually the case by stating that in the afternoon the sun at the same height acts more powerfully because the saturation of the air with water moisture is lower then than in the morning hours on which account the absorption of the sun's rays is less in the afternoon. Lornez[4] gives still another reason. On the southwest side, the dew

[1] Holzner, Die Beobachtungen über die Schütte der Kiefer oder Föhre und die Winterfärbung immergrüner Gewächse. Freising 1877.

[2] Wollny, Untersuchungen über den Einfluſs der Exposition auf die Erwärmung des Bodens. Forschungen auf dem Gebiete der Agrikulturphysik. Vol. I, p. 263.

[3] Kerner, Ueber Wanderungen des Maximums der Bodentemperatur. Zeitschr. d. österr. Ges. f. Meteorologie. Vol. VI, No. 5, pp. 65 ff.

[4] Lorenz und Rothe, Lehrbuch der Klimatologie. Wien 1874, p. 306.

and moisture from the rain have dried up more than on the south and southeast; it has previously been warmed to some extent and the same amount of warmth falling on a drier soil correspondingly warms it up more.

The monthly mean temperature, however, and in any case the maximum warmth in the different seasons, is more important for plants than is the annual average. In this connection Kerner's thermometer observations show that *only in winter (from November to April) is the maximum soil temperature found on the southwest side and that conversely, from May until August, the southeast side shows the greatest warmth; in September and October the south side is the warmest.* This shifting of the maximum may undoubtedly be explained by the dry east and southeast winds of midsummer which, a similar physical composition of the soil being assumed, dry the soil more quickly and thereby make it more capable of being warmed up.

While Kerner's investigations were made on a natural hill, consisting of alluvial sand and provided with pretty steep, grass slopes near Innsbruck, Wollny experimented with an artificial hill made of sifted calcareous sandy humus whose surface formed an angle of 15°. Here, therefore, the conditions were adapted to a land which could be used agriculturally.

Wollny's observations confirm first of all those of Kerner, that the maximum of warmth shifts from southeast in summer to southwest in winter. Further, in general, *the southern slopes (S.W., S., S.E.) are exposed to greater fluctuations in temperature* than the northerly slopes which respond to the smallest fluctuations. In another series of experiments ascertaining the temperature of the slopes of beds set at different angles to the compass, compared during the warmer season with the temperature on a level field surface depressed 15 cm., gave the following results. The south side is the warmest, then follows, as the medium, the level worked surface; then in the third place the east and west sides, while the northern exposure of the bed seems to be the coldest. If now the bed is placed east and west, one long surface lying to the south, the other to the north, these two surfaces show the greatest difference in temperature when vegetation can still be found. Therefore, if the field is to be laid out in plots, it is better to have them run north and south. Cultivation on level surfaces with a lower temperature than on the slope inclined to the south but exceeding that of other exposures is the most advantageous on account of the even, and, on an average, higher warming of the soil.

Later experiments[1], however, show the advantages of a position inclined to the south, but these are only evident when the moisture is sufficient and constant. In dry weather or irregular precipitation the harvest is smaller. Indeed, in extremely dry weather, the greatest yield is from the northerly side, which otherwise gives the smallest. In fact the yield becomes less as the angle of inclination increases. Then follow the west and east exposures. The smallest yield was usually on the south side.

[1] Wollny, E., Untersuchumgen über die physikal. Eigenschaften des Bodens auf das Produktionsvermögen der Nutzgewächse. Forsch Geb. d. Agrikluturphysik XX, Part 3, 1899, p. 291.

Naturally other conditions also enter into the question; thus, for example, color also becomes a considerable quantity when the soil is sufficiently damp and has a favorable mechanical form. The darker the earth the more plant growth is favored. Mixed soils give better results than clear peat, sand or loamy soils.

a. Too Steep Slopes.

Soil surfaces of more than 15° to 20° inclination in a small area must be used so far as possible for meadow and grazing land if gardening and vineyards do not warrant expensive terracing. If the inclination of any surface approximates 45° it is urgently advisable to retain *all* existing vegetation and to attempt forestration or to complete it with suitable planting.

This utilization of surfaces, at such an inclination, is not only the best method but also the best protection of the lower adjacent cultivated land. Such steep slopes, only found in mountains, rarely have a deep loam even when covered with forests. Under such conditions only the thickly matted root systems of the trees can keep off the destructive gullying and washings after heavy rains and from storms after continued drought if the soil contains much sand. The moss cushions of forests retain moisture necessary for the further disintegration of the rocks and increase the tendency to form springs; which benefit is felt only on the plains. It is easy to observe, that the pith has become eccentric when the trees are growing on steep declivities. Mer[1], studying firs and spruces of the Vosges, observed that, in trees growing on steep cliffs, the annual rings are more strongly developed on the side toward the upper incline than on that toward the declivity. This occurs especially at the base of the trunk. On cliffs lying toward the north and east, the firs and spruces were not only taller and stronger but the annual rings of the individual trees varied more markedly in the same points of the compass. If the trees have to grow twisted, the annual rings show a stronger development on the convex side at the points of twisting.

Unfortunately our cultivated lands show the sad results of the deforestation of steep slopes. The forest was here the product of consecutive processes many hundred years old, which probably began with the colonization of lichen encrustations on the naked rock. Through the retention of the products of weathering, these and gradually larger plants began to form a surface soil and with their decomposed bodies furnished the first humus substances, making the soil better and better adapted for the growth of higher plants. Once robbed of this covering of vegetation, the bursts of rain sweep the surface soil downward, exposing the stony sub-soil on the heights and filling up the tilled land on the plains. With greater deforestation of the mountain, the water supply of the mountain streams becomes the more irregular and, with more frequent spring floods in the lowlands, covers them with sand; also in dry summers the streams are without water.

[1] Mer, Des causes qui produisent l'excentricité de la moelle dans les Sapins. Compt. Rend. Vol. CVI, 1888, p. 313.

Aside from the direct injury of the stones carried down with the masses of earth, the chief destruction lies essentially in the covering of the parts of the plants which hitherto had been exposed to the free air. Many plants, however, die if they are permanently planted too deep and only those can withstand being covered with soil which possess the ability of readily striking adventitious roots. Among herbacous plants the grasses growing on dunes should be emphasized especially as having this quality *(Arundo arenaria* L., *Elymus arenarius* L., etc.) ; our quack grass *(Agropyrum repens* P. B.) also easily works its way out through a heavy covering. Among trees, the willows and poplars withstand such a covering without great disadvantage, and especially the (Seekreuzdorn) *(Hippophaë rhamnoides* L.), which grows on gravel and sand, is found on the coasts of Germany, France and England, and serves, with its flat lying roots, as a means of retaining the dunes. In opposition to this, the bases of the trunks of many trees, as for example, fruit trees, are very sensitive to deep, heavy soil covering. Also in transplanting trees, or in grading, a change in level covers the base of the trunk, which has been exposed to the air, leads to a weakening and shows phenomena of disease which will be treated of more in detail. In potted plants the Ericas are most sensitive to the smothering of too deep planting. It must be assumed that the cause of death is a lack of oxygen for the roots which have been set too deep and covered by large amounts of earth.

Landslides, besides covering the lower lands, expose the roots; which fact deserves attention. So long as the forest remains intact, interwoven roots form a network with such small meshes that the soil is held firm. If, however, holes are torn in this by the hand of man or by storms, so that the plants are uprooted, then the soil begins to push down from the higher places and in fact the more quickly, as the soil is more broken and the wind finds the more access to the torn places. Aside from processes of this kind which take place unceasingly in high mountains and before which we usually stand powerless, changes in the forests, even on the plains, take place constantly as a result of the exposure of the roots from the working away of the soil. This is especially the case in forests in hilly places when streets are cut through. The forest soil is usually porous or becomes so by drying and as soon as the street cuts through a hill overgrown with large trees. the free roots are found at the edge of the cut, from between which the soil has fallen out or been worked away. The injury is two-fold since the exposed side of the root crown weakens the anchorage of the trees and the decreased supply of water impairs the formation of the tree top.

The statement that the injury caused by such cutting of the forest for shortening the road is compensated for by the increased growth of trees is an error. To be sure this may, under certain circumstances, effect a considerable increment of growth, as, for example, Hartig's[1] investigations

[1] Hartig, Ueber den Lichtstandszuwachs der Kiefer. Allg. Forst- u. Jagdzeitung. LXIV, 1888, Januar.

show. He found in pines 147 years old which had been standing free for seventeen years, that the growth had been doubled in the first ten years, especially in the lower part of the trunk, where the amount of wood, that is the dry weight, had also increased. But he also demonstrated that the increase fell to the earlier amount, when the food in the soil was taken up by spruces which were set out there. In trees whose roots are exposed on one side, there is a less water content of the soil which also retards the absorption of foods and the influence of light is scarcely able to cause an increase of growth. But even if a considerable increase of growth is obtained by the sudden thrusting of the trees into the light, no agricultural advantage is constantly connected with it. In the first place, the branching is increased and, in the second, the wood due to the rapidly increased growth is coarse grained. This is deduced from the observations of Cieslar and Janka[1] who investigated the spruce wood produced by long-standing cultivation. Produced in great quantity the wood was of strikingly low specific gravity because the autumn wood made a scanty growth and the tracheids, in the main part of the annual ring, were unusually wide. On the other hand, the danger of drying *of the top, or blight of the tip,* often becomes greater. This applies also to deciduous trees grown in dense plantations. The crowns are suddenly freed, their leaves, in structure and function, are adapted to a moderate amount of illumination, can not endure the increased transpiration and the excess of light so that the tips of the branches partially die back. Therefore it is urgently advised in the interest of retaining old tracts of woods, specially in sandy soil, to avoid cutting through the hills to lay out roads, preferably to lay the road out around the hill. According to Hartig[2] the shock of the sudden opening may also lead to injury if, with the increased supply of light, the top is stimulated to too active growth. This continues some years, while the available quantity of nutriment in the soil lasts. Because the leaf material is increased as a result of the intensity of the light, much larger amounts of mineral stuffs naturally are required than with growth in dense tracts. However, when parts of forests are exposed, soluble mineral food material can not be provided in sufficient quantity by the influence of the atmosphere, consequently after a good growing period there is a decrease in growth due to the *"impoverishment of the soil."* Following a scarcity of material, however, no matter whether due to an actual lack of the substance or to its insufficient absorption on the part of the tree, as a result of injuries to the roots or a lack of water, there is not only a decrease of growth but also the constitution of the wood is weakened. As when growth is forced, only the thin-walled spring wood, the vascular tissue, is formed and but little or no strengthening tissue, which is present in late wood.

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1 Cieslar, A. und Janka, G., Studien über die Qualität rasch erwachsenen Fichtenholzes. Centralbl. f. d. gesamte Forstwesen 1902. Part 8.

2 Hartig, R., Ueber den Einflufs der Kronengröfse und der Nahrstoffzufuhr aus dem Boden auf die Gröfse und Form des Zuwachses etc. Forstl. naturw. Zeitschrift VII, 1898, p. 78.

b. Growth of Stilts.

(Elevation of the Roots of Trees.)

In this connection it is advisable to consider still more closely the fact that large forest trees grow with their older root branches above the ground, so that the base of the stem is carried on a number of stilts. This position gives scantier anchorage to the trees and results disadvantageously since they are more easily blown down in wind storms. In addition to this there is a smaller provision of water and the roots are peculiarly sensitive.

These stilted growths form two types; first, in spruces, where the base of the trunk is raised high above the soil and the strong branches of the root crown have never been below the top of the earth; second, in pines, not rare on strongly undulating sandy soil, in which the base of the trunk has previously been covered with soil or may even frequently rest on its surface so that part of the crown is covered with earth, while the other part has been uncovered by the washing away of the soil. In extreme cases the soil slides out from under the trunk so that the whole tree stands on stilts.

Examples of the first type are described and illustrated by L. Klein[1] (Figure 4). He explains the production of the phenomenon as follows:—If spruces or firs have been felled in the mountains a stump is left standing which weathers gradually on its upper surface and becomes covered with moss. Later Vaccinia etc. infest this moss cushion beneath which is produced a thin humus layer. If self-sown spruces or firs begin to grow on the moss-covered surface of the stump, the little young growing roots creep under the moss-covering in all directions over the surface of the stump and then down its sides to the soil, and develop further there, like every other root. In the course of many decades the roots become stronger, the old stump slowly rots away. Klein answers the question, as to why one usually finds spruces much more rarely than firs and never any deciduous trees with this stilt-like growth, when he states that the water needed by deciduous trees is possibly ten times as great as that of conifers and that on this account the seedling of a deciduous tree would not find enough water permanently on the surface of the stump for its development. Even if deciduous trees do not grow on stilts, yet similar structures such as the sheath growth, may nevertheless be found. This occurs especially in willows. Where old willows grow along country roads, one finds at times the appearance of a new trunk growing independently out of the decayed heart of the hollow old trunk, so that the woody cylinder of the old trunk surrounds the young tree like a wide sheath. Such cases are easily explained in the pollarded willows when the crown is entirely cut off every year or every second year, in order to obtain as many young shoots as possible. With the rapid rotting of willow-wood on large pollarded surfaces, soil accumulates very quickly from

[1] Klein, L., Die botanischen Naturdenkmäler des Grofsherzogtums Baden u. ihre Erhaltung. Festrede. Karlsruhe 1904, p. 13, Fig. 7.

be [illegible] blown from the street into the depressions [illegible] in which seeds [illegible] have [illegible] together. [illegible] this space [illegible] rotted wood [illegible] the old trunk [illegible] grows downward [illegible] in the hollow trunk, [illegible]

Fig. 4. Stilted spruce near Schönmünzach in Stubenwasen. [illegible]

A case, due probably to the same conditions, which cause the stilt-like growth of spruces, was shown as recently as the 80's of the last century at Kohlhasenbruck near Neubabelsberg (District of Potsdam). The stump of an old oak, about 75 cm. high, on the village street, had formed a broad hollow cylinder by the rotting of all of the heart wood. [illegible] filled with rotten wood and earth and a healthy oak [illegible] years old stood in this as in a sheath.

In spruce plantations one finds at times [illegible] in which a number of side branches have [illegible]

main trunk which the wind has blown down, part of whose roots, however, still remain in the soil, and therefore are still living. Adventitious roots serve the needs of these growths for nutrition. The spruce is certainly the one of all the conifers which can most easily overcome all injuries by developing adventitious organs.

It also withstands pruning very well and can therefore be used advantageously for hedges, only the hedges must be thinned constantly, or they become bare underneath. The ability to form new tips when the old ones have been removed, a characteristic of spruce and Araucaria, is taken advantage of in horticulture, in propagating by cuttings.

On the other hand, the regeneration phenomena of the older pine are most stable and fixed. The second type of stilt-growth occurs especially with this tree, if, in a hilly place, the porous sandy soil slides downwards from the effects of grading. In the struggle for existence, however, the pine when grown from seed can withstand much better exposure of its roots than spruces and firs; this is because the roots habitually grow perpendicularly into the ground. In the two illustrations which reproduce two examples of *Pinus silvestris* from the Grunewald (back of Paulsborn) near Berlin, this perpendicular downward growth is shown especially well in the side roots.

Figure 5 shows two pines standing back of one another with the bases of their trunks about 1 meter above the ground. The strong main roots send their side branches (arising directly on the underside) into the ground in parallel and perpendicular directions, indicating that the pine roots deeply. The front tree is possibly 60 years old; the specimen behind it is younger. Figure 6 is taken from another side and shows the side roots starting at right angles from the main branches which spread horizontally from the root crowns. However, in the middle of the stilt appearance, may be distinctly recognized the original main root which as a prop has grown directly into the earth and which endures the chief strain of anchoring the tree in the sandy soil. The tree is still well covered with needles.

One more important phenomenon must be mentioned in connection with this form of stilt-growth, viz., many woody tubers with a dense covering of bark grow in rows on the upper sides of the strong roots. These in figure 7, reproduced natural size, form hemispherical, wart-like prominences up to 1.5 cm. high, with a crater-like depressed centre. They correspond with the rest of the root in color and bark.

It is supposed that this arises from an adventitious sprout formation in which the young shoots have died immediately and a heavy scar has been formed. The fact that these growths come only on the upper side lends strength to this supposition. It is well known that when there is this tendency toward adventitious growths in trees, the formation of such buds of all sizes occurs most strongly on the side toward the light (Tilia, Acer). This supposition has not been generally confirmed, as the cross-section (Fig. 8) shows. This illustrates a seven years' overgrowth of a centre of disease formed by a homogeneous mass of resin. This resin gall, produced by resin-

Fig. 5. Stilted pine from Grunewald near Berlin. (Orig.)

Fig. 6. Stilted pine from Grunewald near Berlin. (Orig.)

osis of the wood, ruptured on the outside and was overgrown in the following years. The edges of the overgrowth, still connected in the first few years, have grown back farther and farther;—in this way, a crater-like opening was produced at the top of the woody tuber. The new annual rings turn to resin every year and always in the first spring wood, which consists in part of parenchymatically formed cells. The resin holes *(H)* are produced by the drying up of the resinified tissues, in part also by exudation of the resin. The edges of the overgrowth are further apart each time so that the last ones *(U)* are widely separated. In this, they show a most irregular construction often changing between every two medullary rays in the same annual ring. In the drawing *G* is the normal wood in cross-section and *M* the regular course of the tracheids in longitudinal section. These are in the same annual ring just as in true gnarls.

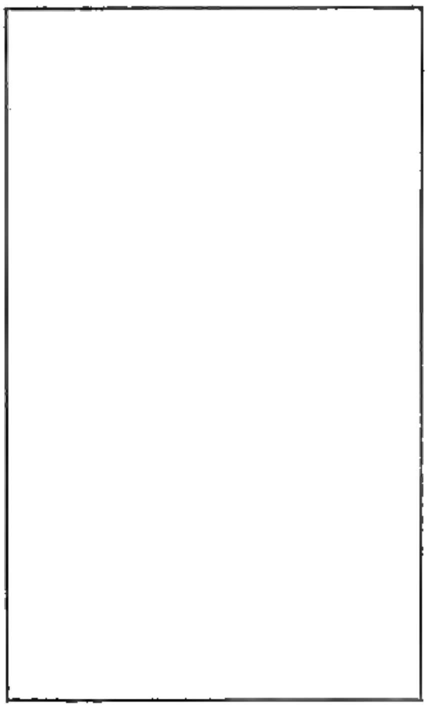

Fig. 7. Resin galls with gnarl growth on the upper side of the stilt-like root of the pine (natural size). (Orig.)

For this reason these structures must be classed with the resin galls. So far as their production is concerned, it must be assumed that the exposed root shows small centres of injury from extremes of weather on its upper side, i. e. the one most exposed to such extremes. These centres of injury have caused a resinosis of the tissues, or rather, a complete resinous liquefaction. We may assume that frost has caused the injuries, and especially late frosts, since these appearances are always found in the first formed spring wood. The production of these resin galls shows that the roots

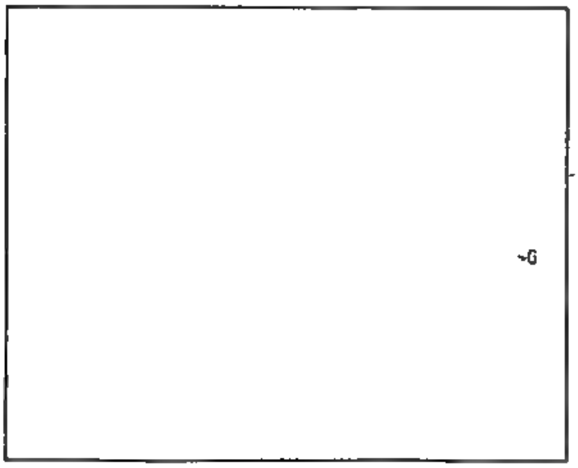

Fig. 8. Cross-section through a resin gall on the stilt-like root of the pine. (Orig.)

exposed in the stilt-like growth are very sensitive. If this is true, less extreme cases will have to be taken into consideration and a further warning be given; when possible the root body must be guarded from complete exposure. When roots are partially exposed their bark is liable to be broken on the upper side by pedestrians, with the result that much stronger annual rings develop on the under side which is protected from such injuries by the earth.

The cultivation of seedlings of the different species of our common conifers under the same conditions gives the best demonstration of these root systems. Nobbe[1] carried his experiments out with the following results:—Six months after sowing, the pines had 3135 root fibres with a total length of 12 meters, the spruces 253 fibres, all together 2 meters in length and the fir, 134 fibres with a total length of 1 meter. In one year, in fertilized sandy soil, the tap-roots of the pine seedling penetrated almost one meter deep, while the spruce and fir, under absolutely the same experimental conditions, went down only one third as far. At the same time the young pine developed five series of roots, the spruce four and the fir three. In deciduous trees, oaks and beeches, Tharandt's experiments showed that in the same way they form even in the first year a widely branched root system with tap roots nearly a meter long.

Spruce and fir with their weaker root apparatus, which almost immediately spreads out flat, need a moist soil, while the pine can do without moisture, in fact, easily suffers from it. In seedling plantations, where fir and spruce thrive, the pine very often shows pathological resin ducts in the wood of its young trunk. The deep growth of the pine also explains its so-called "contentment" and its healthy growth in almost sterile sand. Like the lupin it understands how to meet its need for water and food from the deep layers of the soil, but it demands good drainage.

This natural advantage of a tap root penetrating at once to great depths is made use of only where seeds are planted in forests without necessity for transplantation. In the controversy in forestry circles as to the best methods of planting, in considering the pine, we would always place ourselves on the side of those favoring sowing in the permanent place. For the spruce and fir, we consider transplanting from the seed bed to be more advantageous. In any event the method of seeding is not the only factor in a healthy development, but soil and position are often decisive. We can not consider advisable the present endeavor to plant pines everywhere, because they give the quickest and therefore the best return from the soil. In our own forests comparisons of the trees in deep lying or marshy places with those on free, dry regions show that in the marshy localities there is an impoverished growth and often a premature dropping of the needles, and that in hilly sandy soil, with deep lying ground water, the trees develop to their full strength, even being well-preserved when their roots are exposed on stilts. Rechinger[2]

[1] Döbner's Botanik für Forstmänner. IV Edition, revised by Fr. Nobbe, Berlin. Paul Parey. 1882, p. 130.

[2] Rechinger, Bot. Beobacht. in Schur. cit. Bot. Jahresber. 1902, I, p. 337.

mentions the occurrence of stilt-roots in marshy forests, in which *Alnus glutinosa* predominates while isolated *Quercus pedunculata, Rhamnus Frangula* and *Salix cinerea* occur.

A third cause of the stilt-like growth still remains to be mentioned which is different in that the trees are positively elevated, while, in the cases already mentioned, the base of the trunk remains at the place where the seed was sown. White[1] describes occurrences of this kind. He thinks that on rocky soil, where the roots must grow flat, the trees are gradually forced out of the ground by periods of frost and draught to which they are peculiarly susceptible.

c. Too Deep Planting.

Too Deep Planting of Trees.

Almost all our trees, in their later life, stand in a position different from that of the seed beds in which they develop. For fruit trees must have a second transplanting when young in order to obtain an abundant ramification of the root body. Since these trees must be so transplanted great care should be taken that they are not planted deeper than they originally stood. Experience teaches that trees can indeed be destroyed through a disregard of this warning. In fact many practical workers recommend that each tree in its new position be oriented exactly as before in regard to the points of the compass, since they think that many kinds of bark injuries from heat and frost can thus be avoided.

Otto[2] has attempted to decide the question whether the branches of apple, pear and cherry trees develop differently in the several points of the compass. By chemical analysis, he found essential differences in the composition of the differently oriented one year old branches. The water and nitrogen content is the smallest on the east side, while the content in dry substances is the greatest there; but the water and nitrogen content is greatest on the north side. This would indicate that the branches were not so fully matured here as on the other side of the tree.

Kövessi[3] considers the cause of a decreased formation of blossoms to be the greater amount of water and the lesser ripening of the wood of the branches. The number of blossoms and fruit was certainly proved to be dependent on the water supply of the previous year. The tree bears better, if the water supply is scant. Anatomically, the differences in the maturity of the branches, according to the points of the compass, can scarcely be determined since the structure of the same annual ring fluctuates too greatly within the different internodes of a branch[4].

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[1] White, Theodore, Mechanical elevation of the roots of trees. The Asa Gray Bull. Cit Bot. Jahresb. 1897, I, p. 85.

[2] Otto, Arbeiten der Chemischen Versuchsstation zu Proskau. Cit. Bot. Centralblatt 1900, Vol. 82, Nos. 10-11.

[3] Kövessi, F., Ueber die Beziehung des Wassers zur Reife der Holzpflanzen. Biedermann's Centralbl. 1902, p. 161.

[4] Sorauer, Beitrag zur Kenntnis der Zweige unserer Obstbaüme. Forsch. a. d. Gebiete d. Agrikulturphysik, Vol. III, Part 2.

Also, we know nothing definite, at least nothing which holds good in general, of the anatomical changes taking place when trees are planted too deep. In some cases it has been observed that the ducts are filled with brown, gum-like stiff masses, in others they are filled with tyloses accompanied by a brown discoloration of the walls. Gummy swellings of the membranes are not infrequent. But these are all only occasional observations and experimental study of the question is still needed.

We will limit ourselves on this account to the enumeration of the discoveries already made as to the influence of the two factors occurring most generally when trees have been planted too deeply—the lack of oxygen and the excess of carbon dioxid. We know that plants without a supply of oxygen gradually die. If the living cell can take up no oxygen, it changes the direction of its life-functions. Later it passes over into a state of rigidity, since the phenomena of movement cease in the cytoplasm, the sensitiveness to stimuli is lost and growth becomes inhibited. The plant, however, does not die immediately. It continues to give off carbon dioxid for some time and, with a renewal of the oxygen supply, it can even re-assume its usual functions after a rather long apparent death. In this continuation of life without oxygen (anäerobic) the oxygen necessary for the life processes must be furnished from the substance of the plant itself and has been called *intra-molecular respiration.*

Lechartier and Bellamy[1], in a series of experiments, have proved that alcohol is formed in the parenchyma cells growing without a supply of oxygen, not only in our pitted and other fruits, but also in the roots and leaves. Stocklasa has also proved most recently that there is a formation of lactic acid. Even in fungi *(Agaricus campestris)*, Muntz[2] found alcohol and hydrogen in considerable quantities if the fungi were kept for some time in air free from oxygen. The material for this alcohol can have been furnished by the kind of sugar alone present here, named mannose, while in other fungi, producing only alcohol, (without hydrogen) in an atmosphere of carbon dioxid, the trehalose must have been fermented. If the fungus is not kept too long in the oxygen-free air, it can take up again its normal life-functions, as has recently been proved by Krasnosselsky[3] for *Mucor spinosa* and *Aspergillus niger.* Adolf Mayer[4] had earlier expressed his opinion that fermentation produced by yeast, is a result of respiration in the absence of oxygen. Pasteur[5] and Böhm[6] had really proved already that all more highly organized land and water plants behave in a very similar way, since, in media free from oxygen, they

[1] De la fermentation des pommes et des poires. Compt rend. t. LXXIX, p. 949.—De la fermentation des fruits ib. p. 1006.
[2] Comptes rend. LXXX I, p. 178.
[3] Krasnosselsky, Atmung und Gärung der Schimmelpilze etc. Centralbl. f. Bakteriologie etc., 1904, Vol. XIII. Nos. 22-23.
[4] Mayer, A., Untersuchungen über die alkoholische Gärung. Landwirtsch. Versuchsstationen, 1871.
[5] Faits nouveaux pour servir à la connaissance de la théorie des fermentations proprement dites. Compt. rend. 1872, p. 784.
[6] Böhm, Ueber die Respiration von Landpflanzen. Sitzungsber. d. k. Akad. d. Wissensch. 67. Section I.

reduce a part of their substance by fermentation to carbon dioxid and alcohol, as do the yeasts in self-fermentation. The green parts of plants at any rate, with sufficiently intensive illumination, can establish an atmosphere suited to their normal respiration by decomposing the carbon dioxid which had been given off immediately before. Aërobic and anaërobic respiration are interdependent and anaërobic is able to withstand total destruction for some time, even if growth is impossible This retardation becomes greater as the temperature is lower. Thus, for example, Pfeffer[1] cites the observations of Chudiakow, that the failure of the carbon dioxid production, i. e. the possibility of living, begins after twelve hours in seedlings of maize at a temperature of 40°C., after 24 hours at 18°C. and only after some days at a lower temperature. If an organism or one of its members always has a lower vitality, it also will keep alive longer in a place free from oxygen. Thus, under such conditions, apples and pears at a moderate temperature have been kept growing and ripening for months while rapidly growing moulds and aërobic bacteria went to pieces quickly. In seedlings of phanerogamic plants *(Vicia Faba,* Ricinus etc.*)* there is an increase in the intra-molecular exchange.

Stich's[2] experiments show that single plants at times, or parts of plants, at first exert no influence on the oxygen content in the air by their respiration since, in a hydrogen atmosphere, they form exactly as much carbon dioxid as in air. With 8 per cent. of oxygen in the air, the respiratory quotient was still normal,—with a lesser content (2 to 4 per cent.) it was changed in favor of carbon dioxid because an intra-molecular respiration took place. When the plants were kept for a longer time in an atmosphere poor in oxygen, the normal respiratory quotient was gradually produced together with a decrease of the absolute amount of oxygen and carbon dioxid. In a gradual withdrawal of the oxygen, the intra-molecular respiration is first stimulated by a considerably lower percentage of oxygen than when the oxygen diminution is *sudden*.

Brefeld's[3] experiments lead to the conclusion that alcoholic fermentation in all plants, from the lowest to the highest, takes place as soon as the oxygen supply ceases. A very essential difference is shown, however, in the different organisms which produce alcohol. While generally in yeast (Saccharomycetes) the phenomenon of fermentation is to be considered the climax of the normal activity of the organisms (which actually grow during the process of sugar decomposition), it appears in the cells of phanerogams as an abnormal process ending prematurely in the death of the cell. This differs essentially from the pure fermentation of yeast producing only alcohol and carbon dioxid, by the appearance of further products of decomposition among which fusel oil and acids are especially noticeable. There is a great

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1 Pfeffer, Pflanzenphysiologie, 1897. Vol. I, p. 544.

2 Stich, C., Die Atmung der Pflanzen bei verminderter Sauerstoffspannung und bei Verletzungen. Flora 1891, p. 1.

3 Ueber Gärung III, Vorkommen und Verbreitung der Alkoholgärung im Pflanzenreiche. Bot. Zeit. 1876, p. 381.

difference in the ability of fungi to endure alcohol, as is shown among those which still introduce an actual alcohol fermentation. For Saccharomycetes, 12 per cent. of the weight is the limit of growth; 14 per cent. the limit of fermentation. In *Mucor racemosus,* which lives on sugar without free oxygen, the limit of growth and of fermentation lies between 4½ and 5½ per cent. alcohol; *Mucor stolonifer,* on the other hand, no longer grows and can not begin fermentation with 1.5 per cent. alcohol. It should be concluded from these results that under the same external conditions even phanerogams succeed in forming alcohol of very different percentages and endure it in different amounts.

Later Muntz[1] speaks very generally of alcohol as one of the decomposition products of organic substances formed on the surface of the earth as well as in the soil and in the depths of the ocean and distributed in the atmosphere according to the laws of the tension of gases.

It can not be surprising that organic acids, among others acetic acid, occur in the fermentation of alcohol. It is very probable that the accumulation of such acids must ultimately act as a poison upon the organisms and that in roots, which are entirely or almost entirely cut off from atmospheric oxygen, there will begin a gradual dying back.

When trees have been planted too deep and the roots need an abundance of air, perhaps more than the top part of the plant, the lack of oxygen will be felt more quickly the greater the power of the soil to hold water and the more the parts are cut off by water[2]. Water near the living roots becomes more and more a source of danger for the larger, healthy roots and for the sunken bases of the trees, since the water becomes more and more charged with carbon dioxid. If healthy plants are set in water containing much carbon dioxid they begin to wilt and the leaves begin to die back[3]. Kosaroff's[4] studies on the absorption of water in insufficiently drained soils, i. e. those poor in oxygen and rich in carbon dioxid, are especially interesting. The water absorption and transpiration were proved to be repressed by the carbon dioxid. Plants whose roots remained in an atmosphere rich in carbon dioxid lost their turgidity immediately and became limp; when kept there longer they disintegrated. In experiments in an hydrogen atmosphere where, therefore, only the lack of oxygen becomes depressing, it was shown that this circumstance does not act in any way as injuriously as an excess of carbon dioxid.

Therefore, in the roots of trees lying too deep, death by poison begins by attacking first the tender organs, later the older ramifications of the roots. At the same time the putrid products of decomposition make the whole soil unfit for the growth of plants. Böhm[5] cites an example in the dying

[1] From Compt. rend. Vol. LXXXXII, p. 499. cit. in Biedermann's Centralbl. 1881, p. 709.

[2] Mayer, Agrikulturchemie, 5th Edition, 1901, Vol. I, p. 116.

[3] Wolf. W., Tageblatt der Naturforscher-Versammlung zu Leipzig, 1872, p. 209.

[4] Kosaroff, Einfluss verschiedener äusserer Faktoren auf die Wasseraufnahme der Pflanzen. Dissert. Leipzig, 1897, cit. Naturw. Rundschau, 1897, No. 47.

[5] Böhm, J., Ueber die Ursache des Absterbens der Götterbäume und über die Methode der Neubepflanzung der Ringstrasse in Wein. Faesy & Frick.

Ailanthus trees of the Ringstrasse in Vienna which had been planted too deep. These trees years before had fallen off in growth, for in the first year after they were planted, their annual rings were more than 3 cm. broad, in the last year the growth was 0.5 cm. At the time of death the earth about the roots was found to be so injurious that seeds of different plants sown in the soil in the open and under bell jars began to decompose at once. Seeds developed luxuriantly, however, after this soil, repeatedly washed with water, had been exposed in thin layers to the atmosphere for eight warm days in July. Similar experiments were undertaken by Mangin[1] who, before this time, had ascribed the diseased appearance of the street trees in Paris to the bad composition of the soil. Seeds and tubers sown in soil removed from around diseased roots showed an interrupted development.

The air tests made near the diseased roots of Ailanthus showed a deficiency of oxygen and a preponderance of carbon dioxid and Mangin[2] suspects that the lack of oxygen may be traced back to a reduction by sulfids. Certainly numerous micro-organisms co-operate in the decomposing process of the roots. However, such an attack by the suitable bacteria would not have taken place if the oxygen in the soil had not begun to be deficient.

When trees with spongy bark have been planted too deep, as in the above mentioned Ailanthus trees in Vienna, the bark under the soil is found entirely rotted away. According to the age and the bark structure of the tree, as well as the physical constitution of the soil, a disturbance of the absolutely necessary circulation of the air will appear sooner or later in the buried base of the trunk. This disturbance will be felt also in both the ventilatory systems of the trunk, viz., in the vascular system of the wood body and the bark system communicating with it by means of small hollow spaces. The green bark parenchyma protected by the more or less strongly developed cork is bathed by the atmospheric air; it penetrates through the lenticels into the intercellular spaces where it circulates. The air penetrates the ducts of the wood, partly through the water from the roots, but largely by diffusion from the sides and is also in circulation, as mentioned above. In fact, as may be assumed from the investigations, of O. Höhnel[3], a daily periodicity probably takes place in this circulation. The ducts originally filled with water are partly or entirely emptied in the course of the day, since the superior and surrounding tissues draw away the water. The transpiring leaf body of the tree needs a very large amount of water and draws it from the wood tissues of the branches which make good their losses from the trunk, in which therefore a suction wave advances down toward the base and thence out into the roots.

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1 Mangin, L., Sur la végétation dans une Atmosphère viciée par la respiration. C. rend. 1896, p. 747.

2 Mangin, L., Sur l'aération du sol dans les promenades et plantations de Paris, C. rend. 1895, II, p. 1065.

3 v. Höhnel, Beiträge zur Luft- und Saftbewegung in der Pflanze. Pringsh. Jahrb. f. wissensch. Bot. Vol. XII, Part I, p. 120.

Since more water is drawn away from the ducts than can be replaced instantly, a space partially filled with air appears in these ducts causing a negative pressure (suction) which is so much the greater the less the amount of air present at the beginning or slowly diffused through the membranes, for so much the more must the originally small volume of air be distended to fill out the hollow space which is always becoming greater. In the night, when the evaporation is arrested or very much repressed, the ducts of the trunk again suck up great amounts of water, in fact, this suction is often increased by the pressure proceeding from the roots which can press so much water into the ducts that a great part passes through the membranes into the surrounding cells and intra-cellular spaces. If this liquid drawn up from the root body or pressed up by it is healthy, a considerable infiltration into the intercellular spaces will take place without disadvantage to the body, as has been shown by Moll[1]. If, however, the water mass is already laden with the products of fermentation from the putrefying root tips, we see that these poisonous substances get into the especially sensitive sapwood and bark and thus the dying back easily spreads.

Trees planted too deep, however, usually die only in heavy soil permanently loaded with water. In light soils they suffer but do not die. If the heavy soil with its water burden surrounds the base of the trunk and prevents intercellular ventilation by means of the lenticels, alcoholic fermentation and the formation of acetic acid must naturally appear in the bark cells and lead to a dying back which is continued radially to the cambial zone and the young sapwood which is especially active in conducting water.

Thus there remains from year to year a cylinder of heartwood in the middle of the trunk which is always becoming smaller and smaller and which usually has to meet the water need of the aerial part. The heartwood which is poor in water, however, is less suited for conducting it and the dead tissues of the wood, which at any rate can still conduct water mechanically, will not be able with their help to meet the need of water in the crown. Consequently, the tree ultimately wilts or fails to put out buds in spring.

The fact that the non-parasitic processes of decomposition in the buried end of the trunk cease near the upper surface of the soil leads to the theory that processes of decomposition are not able to attack healthy plant cells but only those weakened and functionally abnormal. Such weakening is actually present. It was mentioned at the beginning that cells full of life and rich in content, when shut away from the oxygen of the air, begin at once to develop alcohol through the activity of fermentation (alcoholases) which was not present previously and which disappears again if the plant regains its atmospheric air. It has been proved further that the plant, in the absence of oxygen, continues for some time to eliminate carbon dioxid in considerable quantities (respires intra-molecularly) but that these amounts of carbon

[1] Untersuchungen über Tropfenausscheidung und Infektion, 1880, p. 78. Sep. aus Verslag en Mededeèling d. Koninkligke Akad. Amsterdama, cit. in Pfeffer, Pflanzenphysiologie, 1881, I, p. 159.

dioxid are still smaller when the experiments are continued longer than those of plants respiring in air which contains oxygen[1]. Since the carbohydrates (starch, sugar) furnish the material for respiration, it should be assumed from the above facts that these material contents of the cell are made use of abnormally in the absence of oxygen. With Pfeffer[2] respiration can be conceived of as a process set up by two dovetailing processes. The first is the intra-molecular respiration ascertained in the phenomena of fermentation which Borodin[3] named internal oxidation. The second process, possible only with a supply of oxygen from without, is the immediate further oxidation of the products of fermentation in the moment of their production. If this last act, absolutely necessary for the life of the cell, is suppressed, not only the zone of the trunk of the tree, planted too deep and lacking oxygen; loses its respiratory material, that is, always becomes poorer in reserve substance, but it also forms those products which lead to decomposition and the death of the cell. Insufficient respiration therefore is a necessary preliminary condition for the dying back and, to the degree in which the buried part approaches the surface of the soil, gradually getting more and more oxygen, the fermentation will become weaker and weaker and pass over into the normal process of oxidation so that decomposition gradually reaches its limit. It is thus only a question whether the tree has the possibility of forming new roots in the soil above these limits in order to meet the loss of water produced by the transpiration of the foliage. The stunted production frequently observable in early years disappears as the more plastic material can pass downward and be used for the new structures in the wood ring of the trunk and the roots. The more rapid the growth, the greater the energy of respiration (as shown by Saussure) and the more the flat new root body is reached by light, so much the more will the production of carbo-hydrates and its absorption of oxygen and production of carbon dioxid increase[4].

The behavior of the trees planted too deep or only partially buried depends naturally upon their specific character. In willows and poplars, for example, the part sunk in the earth may indeed be found to be dead, but near the top of the soil, the decomposition appears to have been stopped. Numerous adventitious roots have been formed from the trunk which, some time after the tree has been buried, starts a healthy development of the crown. The tree is therefore saved if it is able to produce new roots quickly near

1 Wortmann (Ueber die Beziehungen der intramolekularen zur normalen Atmung der Pflanzen. Inauguraldissertation. Würzburg 1879) states, to be sure, that the amounts of carbon dioxid are equally large in intra-molecular and normal respiration; it seems to me, however, that the short duration of his experiments also caused the observation of the after effects of a previous normal functioning. He, himself, admits (p. 31) that in a longer period with no addition of oxygen a smaller amount of carbon dioxid was produced by the plants under experimentation than had been the case in the constant presence of oxygen.

2 Pfeffer, Ueber das Wesen und die Bedeutung der Atmung. Landwirtsch. Jahrb. 1878.

3 Borodin, Sur la respiration des plantes pendant leur germination.

4 Borodin, Mémoires de l'Acad. impériale des sciences de St. Petersbourg. VII série. 1881.

the earth's surface. It is well-known that Ericaceae and Epacrideae are especially sensitive to too deep planting. In these species the base of the trunk dies even when the root has not suffered very much. When the sapling shows moss and lichen growths at the base, there is every reason for being careful.

In nurseries no one general rule holds good in regard to the depth of planting. Aside from the important physical composition of the soil much depends in grafted trees upon the stock. Fruit varieties grafted on wild stock should be so planted that the root neck remains in the plane of the surface of the soil or even projects a little above it. In fact in marshy soil, with a great deal of moisture, planting is made in hills. Pears grafted on dwarf stock (on quinces) and apples (on Doucin and Paradise apples), on the other hand, must be planted at least so deep in the soil that the place of grafting is found at the surface level of the soil; i. e., the whole stock under the soil. From this a considerable number of adventitious roots develop which are especially useful for nutrition.

Bouché[1] has given a splendid summary of practical experiments. He refers first of all to the fact that in old healthy trees the strong roots are seen to appear above the soil and that this appearance of the root neck is normal. Many trees can survive deep planting when young, since they put out new roots from the base of the trunk just below the surface (elms and lindens); others, on the contrary, are very sensitive, as, for example, pears, maples, oaks, most of the Rosaceae, plane-trees, walnuts, red and white beeches. Also most conifers require care in planting, as, for example, the genera Pinus, Picea and Abies and at times also Thuja, especially *Thuja (Biota) orientalis* and related species, while deep planting has been proved to have been endured by *Thuja occidentalis, T. Warreana, T. plicata.* Bouché found trunks 5 to 8 cm. thick putting out a number of new roots from their buried bases whereby they were very much strengthened. *Juniperus communis* must be planted shallowly but *J. Sabina* and related species survive deep planting with advantage. It has already been stated of poplars and willows that deep planting is counterbalanced at once by the formation of new roots on the surface of the soil. In weak trunks it is often found that the roots formed just below the surface get the upper hand over the older, deeper ones. It is actually even more advantageous to plant many bushes deeper than they stood before because they strengthen themselves by numerous new roots from the buried base of the stems. This is noticeable for example in Calycanthus, *Cornus alba* and *C. sibirica,* Ribes, many kinds of Spiraea, *Viburnum Opulus, Aesculus macrostachya,* Symphoria, Ligustrum, *Rosa gallica* etc. On the other hand Caragana, Berberis, Colutea, *Cornus mascula* and *C. sanguinea,* Corylus, Cytisus, Rhamnus, Sambucus, should be planted at the old level.

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[1] Bouché, C., Ueber das Tiefpflanzen von Bäumen etc. Monatsschr. d. Ver. z. Förd. d. Gartenb., v. Wittmack, 1880, p. 212 and Wredow l. c. p. 75.

In planting streets, besides the embankment which sometimes becomes necessary, *the asphalting and cementing of the street causeways* is also very injurious to the roots of the trees. The injury is due not only to the shutting off of the atmospheric air but also the loss of precipitation from the air, upon which trees in large cities become so much more dependent, as the level of the ground water has fallen because of canalization and the workings of the subsoil in building. Young trees which are planted after the *falling of the level of the ground water* strive to reach this despite the increased depth of the springs. Consequently in order to facilitate this, the holes for planting the trees must be made considerably deeper in such localities. According to Bouché, this increased depth amounts to 60 cm. in Berlin so that now the holes for planting trees must be dug 1. 5 cm. deep.

Too Deep Sowing of the Seed.

The discovery has also often been made that from a plentiful sowing of good fresh seed a comparatively small number of plants is produced. As is generally believed, the cause lies more frequently in sowing the seeds too deep. When harrowed in or hoed under in places, as is customary with barley[1], some seed grains necessarily come to lie too deep, others too superficially. Uniformity can be obtained only by planting with a drill. But even the gardener, who can cover his seeds very uniformly in seed pans, not infrequently obtains only a low percentage of plants in sowing very fine seeds even if the seed was good and of high germinating quality.

The processes causing the loss, however, are not always the same, and do not always take place under the same conditions; on this account it is impossible to generalize. In order to protect oneself from injury in this connection, there is nothing to be done except to understand clearly the influence of the different factors to be observed in sowing seed and to see which combinations exist in every individual case.

There are three phases in germination. Each can be disturbed and cause failure. The first stage consists of the *swelling* of the seed and is a mechanical process, in which (probably by water condensation) an increase in temperature has been observed. This introduces the second stage, the *mobilization* of the *reserve substances,* a chain of chemical phenomena, and these accompany the third act, that of the *formal development.*

Disturbances in the stage of swelling have often been observed. Nobbe and Haenlein[2] found especially in Papilionaceae and Caesalpiniacea, that the seed shell at times is so hard that water can not enter, that the seeds retained the embryo for years without development, but always in a healthy condition. The seed did not germinate because it did not swell. In clover seed, the superficial shell or hard layer containing the coloring matter, is

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[1] Eggers-Gorow, Versuche über den Nutzen oder Nachteil einer flachen oder tiefen Bestellung der Gerstenkörner. Mecklenb, landw, Ann, 1874, No. 23.

[2] Nobbe und Haenlein, Ueber die Resistenz von Samen gegen die äufseren Faktoren der Keimung. Versuchsstationen 1877, p. 71.

shown to be so *impermeable for water* that clover seeds can lie from one to two weeks in English sulfuric acid, and for years in water, without losing the coloring matter which in itself would be soluble in water. In such cases only *mechanical treatment* is of any use. Galter and Klose[1] mixed the seeds of lucerne (alfalfa) and varieties of clover with fine sand and trod for ten minutes on the bag containing the mixture. After this treatment, 13.4 per cent. of the seeds of the lucerne were found to be more capable of swelling, 10.2 per cent. of the white clover and 37.8 per cent. of those of the bird's-foot, without showing any especial injury. Nobbe cites examples[2] of an unexpectedly *long retention of the germinating power.* 32 per cent. of seeds of *Pinus silvestris,* gathered in 1869, after having been kept 5 years in closed glasses in an occupied room, still germinated, and after 7 years 12 per cent. With red clover seeds *(Trifolium pratense),* preserved in the same way, 10.5 per cent. germinated after 12 years, peas *(Pisum sativum)* 47.7 per cent. after 10 years, *Spergula arvensis* 20 per cent. after 12 years, flax *(Linum usitarissimum)* 49 per cent. after 6 years and 3 per cent. after 11 years. Out of 400 seeds of the locust *(Robinia Pseud-Acacia)* after ten days, longer than which the time for practical purpose does not last, 71 grains germinated; at the end of the year, 55 grains; in the next year 18; in the following year 7 and, after 7 years, one seed; all were kept continuously in distilled water which was renewed periodically. From these observations it seems credible to us that many buried seeds, unimpaired in life-power, survive for very long periods. Even in the locust seeds mentioned above, the remainder, left ungerminated after seven years, was still perfectly healthy. A slight injury to the seed shell resulted after a few hours in a swelling up and also, as a rule, in rapid germination.

Disturbances of the second phase of the process of germination, the stage of chemical action converting the solid reserve substances into the easily transpired constructive matter, are observed very frequently. The fact that many hard seeds such as Crataegus, Rosa, Juglans, Prunus, lie unharmed for a year in the soil, is not to be confused with real disturbances. The difficulty of swelling may partly be to blame here;—during the dry time in summer the seeds again become dormant. On the other hand water may have permeated them already and have given rise to the formation of ferments, which lead to the mobilization of the reserve substances. But this action of the ferment is in itself too slow, up to the beginning of the dry summer period, to sufficiently nourish the embryo. In different individuals and varieties of all species which germinate with difficulty, germination and development is found the spring following autumn planting. This takes place especially if the seeds are sown soon after harvesting and when possible with the entire fruit. *"Stratification"* has been proved still more effective, i. e. the placing of the seed in layers in vessels filled with sand for the

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1 Galter und Klose, Quellungsunfahigkeit von Kleesamen. Wiener landw. Zeitschr. 1877, No. 17, cit. Jahresb. f. Agrikulturchemie, XX. Year, 1877, p. 181.

2 Döbner's Botanik für Forstmänner, 4th Edition, revised by Nobbe, 1882. p. 382.

winter. The actual disturbances are found to be the lack of external conditions necessary for germination. Besides moisture and warmth there belong here the unimpeded supply of oxygen and the observance of the time when the seed is capable of re-acting.

The time within which the seed responds to the action of the external conditions necessary for germination by a normal transmutation of the reserve substances and the development of the embryo varies greatly, for the different families and species, even for individuals of the same variety. It is well-known that seeds of willows, poplars and elms must be sown immediately after harvesting, since they lose their power of germination after a few days or weeks, while cucumbers and melons often give stronger, more fertile plants, if the seeds have been kept for a year. To be sure, the seeds of many of our fruit and forest trees usually germinate after one or more years, but *the number of the slow growing, weakened specimens increases with the age of the seed.*

Oxygen should be considered the most important factor next to water, necessary for swelling. For germination the seeds never need as much water as their substance can take up; the vegetative activity of the seedling begins before this time[1]. If in the beginning there is a scarcity of water which can be taken up endosmotically, the seed also takes water up hydroscopically from the atmosphere[2]. Water vapor also condenses on the outer surface; in fact, after the manner of all porous bodies, it condenses also hydrogen, nitrogen oxygen and other gases. Dehérain and Landrin[3] found that the swollen seeds take up comparatively more oxygen than nitrogen from the atmosphere so that more nitrogen remains in the enclosed space. After three days the seed begins to give off carbon dioxid and this increases so fast that soon more carbon dioxid is present than the oxygen enclosed in the volume of the air would warrant, the oxygen has gradually disappeared. The excessive production of carbon dioxid is therefore to be considered as a product of the processes of oxidation of the inner burning, beginning in the seeds.

These authors pictured to themselves the beginning of the chemical actions in the seed in such a way that the rapid condensation of the gas determined at first for the various seeds will necessarily free the latent warmth of the gas and this warmth sufficiently increases the temperature of the enclosed oxygen so that oxidation can begin. With this is given the impetus for the normal solution of the reserve substance of the seed; the heat, freed by oxidation, favors these processes more and more and they become evident externally by the production of carbon dioxid.

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1 Jahresb. f. Agrikulturchemie, 1880, p. 213.

2 Hoffmann, R., in the Jahresbericht der agrikulturchemischen Untersuchungstation in Böhmen, 1864, p. 6. and Haberlandt, F., in Zeitschrift für deutsche Landwirte, 1863, p. 355. Both works may be found in abstract in the Jahresb. f. Agrikulturchemie, Jahrg. VII. 1864, pp. 108 and 111.

3 Compt. rend. 1874, Vol. LXXVIII, p. 1488, cit. in Biedermann's Centralbl. f. Agrikulturchemie, 1874, II, p. 185.

The preparation for the germination of the dormant seed, according to this theory, is the loosening undergone by the shell of the seed, as the result of its swelling with water. The broken cell layers which have become permeable for gases now permit their rapid penetration and their condensation therefore gives the first impetus for the process of oxidation which causes the transformation of the reserve substances into diffusible forms. Since it can be observed with the seed albumen of plants that the breaking down of the starch in the seedling begins in the cotyledons in monocotyledons, it can be assumed that the part richest in nitrogen, i. e. the embryonic tissue, under the influence of oxygen will begin the metabolic reactions and by the development of abundant enzymes act upon its surroundings.

The disturbance in the second phase of germination can result only from a lack of oxygen or also from an excess of carbon dioxid. The statements of Th. de Saussure confirmed by Dehérain and Landrin show *that no gas is so detrimental to germination as carbon dioxid.* Seeds which are kept in a mixture of oxygen and hydrogen germinate just as in atmospheric air; yet an addition of a few hundredths of carbon dioxid to an atmosphere of oxygen is enough to absolutely inhibit germination, when only the little roots have appeared. If the amount of carbon dioxid is very considerable seeds will not germinate.

Carbon dioxid in excess is very injurious to other dormant parts of the plant. Van Tieghem and Bonnier[1] found in bulbs and tubers (Tulipa, *Oxalis crenata)* which respired further in air containing a great deal of oxygen, and therefore, produced carbon dioxid, that they formed alcohol in an atmosphere of pure carbon dioxid. Tulip bulbs which had been kept for a month in air free from oxygen were suffocated and remained without further development.

When seed has been sown too deep there is also an excess of carbon dioxid and a lack of oxygen. The thick soil covering brings about injuries and hinders the germination of the seed but can not, however, be expressed in definite figures. Aside from the different requirements of the different species, the optimum thickness of the covering differs for the same species according to the composition of the soil, the amount and distribution of precipitation etc. On this account the results of the experiments often undertaken to ascertain the best depth for sowing differ from one another as soon as a definite statement of figures is undertaken. They all agree, however, that in doubtful cases it is better to sow with too shallow a covering than too deep.

The *purpose of the covering* is to hold the young seed firm and to retain a sufficient degree of moisture. The shutting out of light comes less under consideration. The retention of sufficient moisture for germination must be primarily considered. If enough is present, the roots themselves will penetrate at once into the soil even when the seed lies superficially. On this ac-

[1] Bulletin de la société botanique de France, Vol. XXVII, 1880, p. 83, cit. in Wollny's Forschungen auf dem Gebiete der Agrikulturphysik.

count a perfectly superficial sowing of the seed would be advisable if periods did not occur in spring which dry up the surface of the soil to such an extent that a temporary or even a permanent inhibition of the life activity takes place in the seedling.

The more porous the soil, the greater is the danger of drying out and therefore the greater the depth at which the seed must lie. In regions where the spring is dry a heavy soil will give a more uniform germination even if the sowing is shallow. The same soil and the same depth of sowing become dangerous when strong rainfall and great heat alternate rapidly and form crusts on the upper surface of the soil cutting off nearly all access of air to the seeds then in a most active stage of metabolism. The air enclosed in the seeds does not last long. Ventilation of the plant body is, however, absolutely necessary, even the germinating seed suffers extremely if the air contained in it be removed. The formation of *heavy crusts on the soil* can make the depth of sowing of the seed become the cause of considerably injury, which in itself would not be injurious.

How much the lack of air influences the germination capacity of seeds is evident from de Vries[1] citations. In this connection Haberlandt injected curly beet seeds with water under an air pump and observed that the seeds took up 71.13 per cent.; of these seeds thus partially *deprived of air* only 30 per cent. germinated as against 90 per cent. of the normal seeds kept as a control. In a second experiment all the air was replaced by water forced in by the air pump and only 8 per cent. germinated as against 72 per cent. in the control.

Also the time required for germination was shorter in the normal seeds. It may well be assumed that the removal especially of oxygen from the seed and the hindered diffusion of this gas in new quantities into the intercellular spaces is the cause of the loss in germinating power. Dutrochet[2] found even in mature plants that death often occurs if water is injected. In the *rapid thawing of frozen fleshy parts of plants* which, as a result of an infiltration of the intercellular spaces with water, have a glassy, translucent appearance, the exclusion of the air from the cells by water may contribute essentially to their death.

From the many experiments carried out practically in order to obtain precise numerical values for the *best depth for sowing seeds,* those of Roestell, Tietschert, Ekkert and Wollny are the most thorough. Roestell[3] gives 2 to 4.5 cm. as the most favorable depth for porous, strong, field soil.

Tietschert[4] experiments endeavor to determine the maximum boundaries of the most favorable seeding depths in soils differently constructed physically;—10 cm. was seen to be the rational maximum depth for

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[1] De Vries, Keimungsgeschichte der Zuckerrübe, Landwirtsch, Jahrb. v. Thiel 1879, p. 20.

[2] Dutrochet, Mémorires etc. édition Bruxelles p. 211, cit. by de Vries l. c.

[3] Annalen der Landwirtschaft, Vol. 51, p. 1.

[4] Tietschert, Keimungsversuche mit Roggen and Raps. Halle. 1874.

sandy soil, 8 cm. for humus soil and 5 cm. for clay and loamy soil containing lime.

The last two kinds of soil suffer from dry weather so that shallow seeding gives poor results. The experiments repeated later in the year (August to September) gave for all kinds of soil a depth of 2.5 cm. as very unfavorable because of drought; in this case clay soil was proved most favorable in seeding at a depth of 10 cm. It is evident from this that definite figures must be accepted with great reserve. Ekkert[1] experimented with rye, oats and barley, in loam, in pond slime (silt), in sandy soil and garden earth. In seeding rye in separate wooden boxes no difference in the growth of the plants was shown between 2 to 8 cm. of covering (as a result of uniform ventilation from all sides). In experiments in the open ground stem formation seemed more favored by a lesser depth of the seed, yet this refers more to the time of the appearance of the sprout than to its quality. Oats and barley survive a deeper sowing than does rye. In summer a deeper sowing of the seed is better than in winter. The minimum covering for grain may be 1.5 to 2 cm.; the maximum favorable for results is 6 cm.

Later experiments of the same author[2] bring another important factor into consideration which for the same soil acts as a modifier of the favorable depth for sowing. The *quality of the seed* is at times decisive. The quality of wheat seed, however, with which the first experiments were made did not seem to have any influence on the capacity for germination but the development of the young plant with equal depth of sowing was better, the better the quality of the seed. With a medium 5 cm. depth of sowing (experiments with sandy soil) all qualities gave the longest straw and the longest heads. The relation of the weight of the grain yield to that of the straw is lower, as the seed is poorer and the sowing deeper. Experiments with barley confirmed the results obtained with wheat; the less the depth of sowing and the better the quality used for the same depth the earlier the seed sprouted. The sum of the sprouted plants was no less with inferior seed but the influence of the depth of sowing was so felt in this quality that a shallow sowing gave a much longer straw. In general it must be said that the depth of sowing, conditions otherwise being thought equal, will influence first of all those developmental stages which are connected with the early stage. However, the quality of the grain depends upon the early development in the number of sprouts and the length of the heads as well as the formation of the young heads and is therefore influenced by the depth of the sowing. On the other hand the quality of the harvested grain depends upon the nutritive and weather conditions of the current year, and will therefore be scarcely more influenced by the first development or inherited peculiarity of the grain.

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[1] Ekkert, Ueber Keimung, Bestocking und Bewurzelung der Getreidearten etc. Inauguraldissertation. Leipzig 1874.

[2] Ekkert, Kulturversuch mit Weizen und Gerste verschiedener Qualität etc. Fühling's Landw. Zeit., 1875, Part 1; 1876, Parts 1 and 2.

Soaking of the seed, which has often been recommended for light soils when the time for seeding has been continuously dry, should be used with due care. If the weather becomes dry and the water which has been taken up in swelling is not enough to make the primary rootlets grow into the soil, then there is an unavoidable interruption in growth. This is the explanation of Wollny's discovery[1] that soaking produces plants maturing later.

Wollny's[2] studies on the suitable depth of sowing are most thorough; he determined for grain that sowing 2 to 3 cm. deep furnishes the

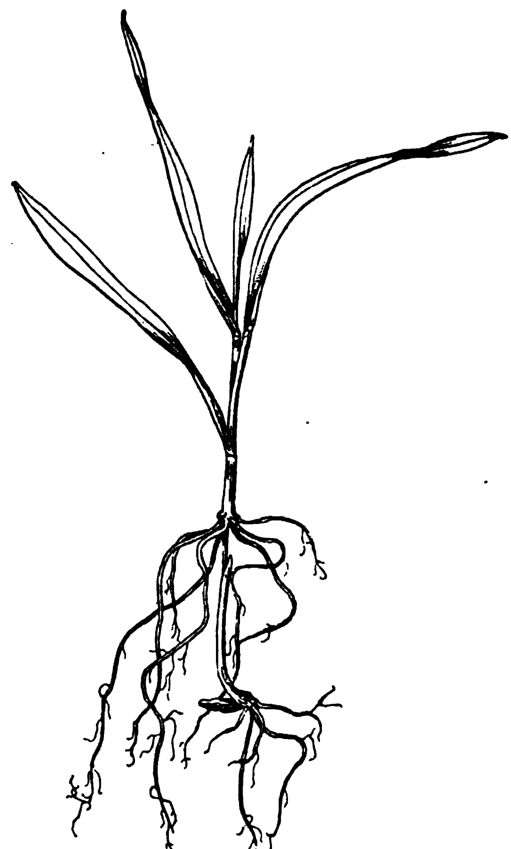

Fig. 9. Rye seedling with too deep sowing of the seed grain. Elevation of the node of the sprout near the surface of the soil. (Orig.)

best results in yield. Over and above this a noticeable retrogression is found already especially emphasized by Jörgensen[3]. The last named author also found rye to be the most sensitive and wheat the least sensitive. For most of the Leguminoseae the depth of the sowing is less important. In contrast to this, varieties of clover and rape have been proved very dependent

[1] Bot. Centralbl., Vol. XXX, No. 15, 1887, p. 48.
[2] Wollny, Saat und Pflege der landwirtschaftl. Culturpflanzen. Berlin, 1885.
[3] Jörgensen, S., Versuche über das Unterbringen der Saat etc. Annalen d. Landw. in d. Kgl. Preuss. Staaten. Wochenblatt 1873. No. 11.

upon the depth to which the seeds are covered. It seems desirable to have this still less than for grain (0.5 to 2.6 cm.). Wollny's experiments showed that in dry years a deeper earth covering was more advantageous, in wet years, a lighter one. Corresponding to wet and dry weather the time of harvest was retarded with an increasing depth of sowing, the number of plants, which germinated at all and still more, the number which came to harvest, was decreased. But it must be emphasized again and again that precise figures for the most favorable sowing in the different localities can be collected only directly by the local agriculturalist since not only the composition of the soil and the weather but also the character of the variety must be considered in the matter, as has been shown by Stössner[1].

This same holds good for tubers, bulbs and pieces of roots which are used for seeds. In these the soil conditions have an especial weight because these fleshy organs which are rich in water are essentially and quickly influenced by the soil supply of oxygen . For potatoes, experiments by Nobbe[2] and Kühn[3] have shown that in questionable cases the more shallow sowing will be the most advantageous one. In the forcing of blooming bulbs excessive losses arise at times from the fact that the bulbs (hyacinths) have been planted too deep in the pot, or when in the pots are covered too deep with earth after the rooting has been sufficient. Especially if the soil covering is heavy and damp and the bulbs have not matured sufficiently the year before on account of wet weather, the "Rotz" (see this in Vol. II.) usually appears very easily.

The *automatic regulation of the depth* of sowing on the part of different plant races is interesting. In grasses, and in fact, best seen in our grain species, the first internode is the part which is destined, when the seed grain has been sown too deep, to push the second node which hides the stem eye and the side buds, i. e. the node which forms the stem, into the porous, well ventilated upper layer of soil. In the adjoining figure 9 we perceive the seed grain which is already almost empty and its weakly retained (primary) roots which had been formed in the grain. From the seed grain the first (over-elongated) internode has pushed the second node nearly up to the upper surface of the soil. In this favorable position the secondary roots, which exist during the whole life of the plant, have been developed, the eyes of the side shoots have attained a further maturity. In shallow sowing both nodes lie close to one another and give in cross-section such a picture as is shown in figure 10. The nodal tissue seems divided radially by browned vascular strands. The vascular-bundle cylinders are those of the primary roots and become diseased during or soon after the formation of the secondary roots. The ground tissue of the node shows the first circle of vascular bundles *(g)* of the young blade close to the pith shield *(m)* with its few cells. Branches of these bundles, recognizable from their wide ducts *(g')*, may be seen fur-

[1] Stössner, Untersuchungen über den Einfluss verschiedener Aussaattiefen etc. Landwirtsch. Jahrbücher 1887.

[2] Nobbe, Handbuch der Samenkunde, 1876, p. 184.

[3] Kühn, Berichte aus dem physiolog. Laborat. Halle, Part I., p. 43.

ther out in the axis. This young blade possesses on the side marked *V* uniformly connected bark tissue; on the opposite side *D*, however, the first sheath-formed leaf *(sch)* which remains colorless, and the bud of the next higher leaf, the first green one *(bl)*, which is completely developed later, have been differentiated from the bark tissue. In the axis of this first leaf may be seen the meristematic position of the first lateral bud *(kn)* which pushes out the green leaf lying in front of it with its already clearly developed epi-

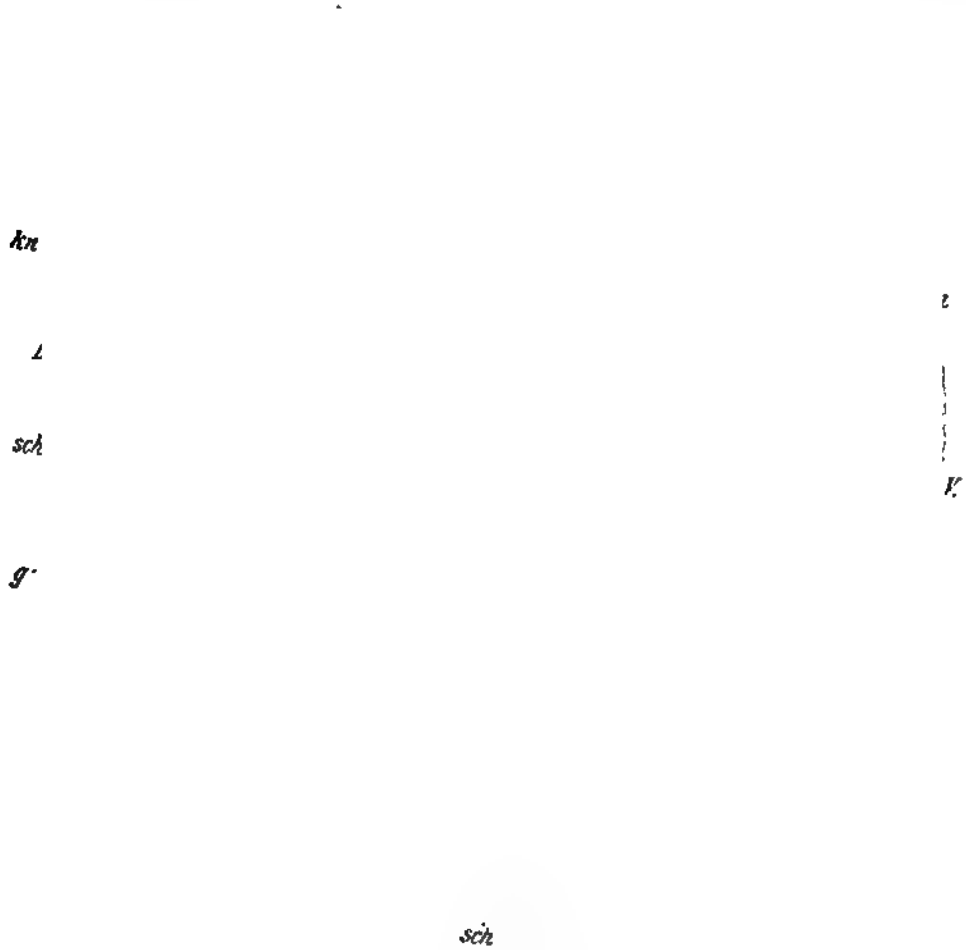

Fig. 10. Cross-section through the lowest node of a young rye plant. Explanation of lettering in text. (Orig.)

dermis *(e')*; *e* is the epidermis of the sheath leaf which is already being differentiated from the axis. If the (dotted) tissue of the bud of the first green leaf *(bl)* be traced backward in this cross-section toward the side marked *V* it is seen that this passes over into a colorless tissue ring characterized, however, by its comparatively large intercellular spaces containing air *(i)*; the bark tissue of the young blade. It is seen from this that each grain leaf is a direct continuation of the bark of the blade. This bark ring

is connected on the side *V* with the tissue of the sheath leaf and it is worth noting that this sheath, even in so young a stage of blade differentiation, must have finished its work since the tissue is entirely impoverished and begins to be full of holes *(l)*.

While therefore in the Gramineae the accessory apparatus, which with too deep sowing brings the vegetative tip into the abundantly aërated particles of soil, consists in the elongation (observed up to 9 cm.) of the lowest internode and, in case of necessity, also of the one above it, we find in the Leguminoseae and other dicotyledons a different arrangement. In beans, for example, we notice first of all an increased elongation of the hypocotyle corresponding to the need, so that finally, with very different depths of sowing, the growing tip of the stem in all plants is found at approximately the same height. Naturally the strength of the plant from the same kind of seed is decreased as the depth of sowing is greater. The more the hypocotyle must be lengthened, in order that its upper part, comparable to the curved back of the burden-carrier, can break through the load of the soil and bring the cotyledons to the light, the more reserve substances will be used up. It is therefore very evident that plants coming from greater depths are weaker even if they have not lost reserve substances in the seed through strong intra-molecular respiration. Such will be the case, however, if continued wet weather sets in after too deep sowing so that a shortage of oxygen results.

The experiments by Godlewski and Polzeniusz[1] show what amounts of reserve substances can be lost through intra-molecular respiration and the formation of alcohol. Sterilized peas, in evacuated air, produced in the first period almost as much carbon dioxid as in normal respiration in the air. The whole amount exceeded 20 per cent. of the original dry substance of the seed. The amount of alcohol formed corresponds to that of the carbon dioxid. Only during the sixth week did the production of carbon dioxid cease in the peas which lay in sterilized water and up to that time possibly 40 per cent. of the dry substances present had been broken down to alcohol and carbon dioxid. This is also the case in grains. In grains the action of the secondary roots on the nodes of the stem counteracts this weakening. In legumes a similar process of self assistance can now take place, since, as Wollny proved, adventitious roots are formed from the over-elongated hypocotyle member. He observed this on the parts of the stem which had been covered with soil, not only in field beans, but also in peas, sweet peas, lentils, lupines and plants of other families,—rape and sunflowers. But the legumes often are not capable of using such an accessory apparatus since, with normal depth of sowing and capacity for germination, they easily succumb to other dangers which will be described in the section on *"condition of hard shells."*

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[1] Godlewski und Polzeniusz, Ueber Alkoholbildung bei der intramolekularen Atmung höherer Pflanzen. Anzeig. Akad. d. Wiss. Krakau, cit. Bot. Jahresb. 1897, p. 142.

ROOTS FROM THE TIP OF GRAIN SEEDS.

It seems best to add here an account of a case which, because of its peculiarity and rareness, deserves a permanent place in science.

The agricultural teacher, Wolfes in Dargun (Mecklenburg-Schwerin), sent me in 1876, fourteen wheat grains in which, through hypertrophy, the embryo did not lie to one side of the endosperm, but occupied a middle position. The grains were sown in the fall and in the spring they had partly rooted but without developing plumules. They were either slender, pear-shaped or even cylindrical at the one end, tapering rapidly at the other like the neck of a violin. In many grains (Fig. 11-12) the elongation of the slender end opposite the embryo was so marked that a neck was formed, possibly 2 to 3.5 mm. long, and twisted toward the upper end.

In twelve grains the length of which varied from ¾ to 1¼ cm. the neck bore a large number of very thin, thread-like roots 1 to 2 cm. long, closely arranged like a brush. These were pubescent almost their entire length.

Upon attempting carefully with a needle to raise the wrinkled and occasionally ruptured testa of the grain it was found to be closely attached to

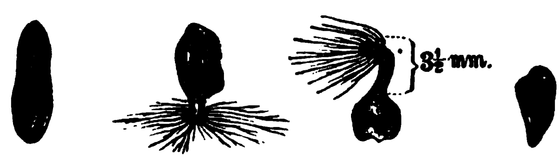

Fig. 11. Wheat grains with roots not originating from the embryo but springing from the hypertrophied testa at the tip of the seed grain.

the grain in different places and, when broken off, was usually of a darker color. On the other hand its upper part was firmly connected with the beak-like growth along almost its whole length and could be raised from the grain proper like a straw cap (Fig. 12). The neck therefore at the time of the investigation was not connected with the actual grain except by the testa from the substance of which it also seemed to be formed. In the fresh condition of the grain this had been firmly set on the seed since various concave places on the inner wall of the cap, perceptible through the microscope, fitted on to the small convex elevations visible on the seed grains.

There was another equally noteworthy phenomenon, namely, that the fissure, normally present, was lacking in these wheat grains. The grain, which had been dug up, also failed to show the seedling which lies at the base of the normal grain and is easily recognizable through the seed coat; it was not noticeable in the seeds observed. The endosperm itself, when cut apart, finally showed only a small degree of the white color of the healthy grain. There were long, glassy, translucent and yellowish streaks extending from the edge inward. It had a rancid odor. The blue iodin reaction for starch was strong only in those particles of the grain which, on the freshly cut

Fig. 12. Wheat grain with hypertrophied testa and root formation at its tip. Embryo central instead of lateral. Explanation of letters in the text. (Orig.)

surface, were found to be white and mealy, while on the glassy places there was only a slight reaction.

The glutinous layer in the Mecklenburg grain was not developed at all, the thin seed shell only incompletely. In place of this glutinous layer (Fig. 12 *k*) a plate-like parenchyma was found, the content of which did not differ essentially from that of the underlying tissue.

The most striking thing connected with this abnormal wheat grain was, however, the position of the embryo on the opposite end from that which bore the roots (Fig. 12 *w*) and exactly in the middle of the grain (as in Typhaceae) equally surrounded on all sides by the tissue of the starch-containing endosperm. While in the normally constructed wheat grain the seedling lies without, at the base of the grain, and is connected with the endosperm by a special organ, the scutellum (the cotyledon), the seedling lies here (Fig. 12 *e*) without cotyledons in a central cavity (Fig. 12 *h*) of the grain.

This cavity in some of the grains is elliptical, in others triangular. In some it extends possibly to the middle of the grain, in others, becoming narrower and narrower toward the top, it reaches to the tip, even penetrating into the tissue of the cap. On the inner side it is lined with a layer formed of two plate-like rows of cells of a glutinous content (Fig. 12 *a*) which clearly resembles the glutinous layer deposited in healthy grains outside the endosperm.

The young leaves of the seedling, folded over one another, show no essential variation. On the contrary, the number of secondary roots formed in whorls at almost equal distances (Fig. 12 *r*) steadily increases up to 6 to 8 and these roots appear to be covered by a parenchymatous layer arranged in the manner of cork cells, 6 to 8 cells thick and free from starch.

On this tissue lies the combined and modified seed coat (Fig. 12 *sf*) which in dry grain becomes thicker walled with more abundant cells toward the tip and develops imperceptibly into the cap which the root bears at its tip (Fig. 12 *w*).

The vascular bundle is continued into the cap from the roots. Here are often found several bundles united at the tip of the cap into a ring-like, thicker network of ducts running horizontally and resembling a node of the stalk.

Still further back from the tip these vascular bundles (Fig. 12 *g*), isolated near the outer edge of the inside of the cap, are seen to run backward (Fig. 12 *gg*). The endosperm normally has no fully developed vascular bundles and the cotyledons only embryonic ones. Here, however, the vascular bundles take an often irregular course through the endosperm and, in the individual grains, surround the seedling in a semi-circle and have not developed even though the grains lay in the soil over winter.

By cutting cross-sections from the diseased grains and submitting them to microscopic investigation, the probable cause of this striking mal-

formation was seen at once. The inability of the seed covering to free itself entirely from the grain was due to a connected firm, homogeneous, somewhat dark mass (Fig. 13); the presence of thick, much ramified mycelial threads, often provided with short skein-like groups of branches, could be proved. The threads of the colorless, strongly refractive mycelium grew transversely through the very thick walls (Fig. 13 *m*) of the fruit cells and seed coat which had been merged into one another. The mycelial threads grew more thickly when the cells were richer in content and thinner walled, entirely filling some cells of the endosperm (Fig. 13 *mm*).

Fig. 13. Hypertrophied testa traversed by mycelia.

Near such places the starch had been dissolved and the cytoplasm had become solid as if it had been dried. In other cells a firm network of protoplasmic material scarcely distinguishable from starch could be seen. These were almost imperceptible in the starch grain but yet were there. This substance was apparently deposited about the starch grains but upon examination there were no grains present, only the corresponding cavities. In some such way originated the yellowish, translucent places between which lay groups of cells especially rich in starch. These mixed regions gave the proper iodine reaction under a weak magnification.

Fig. 14. Normal fruit and seed membrane together with the glutinous layer.

The variation in the structure of the diseased grain is best shown by comparing figures 13 and 14. The latter represents a section from a corresponding part of a healthy gain. The seed coat (Fig. 13-14 *fs*) in the diseased grain is more than three times as thick as in the healthy grain. In the abnormally developed seed coat there is a completely developed vascular bundle with a clearly recognizable sheath (*gs*). In the diseased grain the growing fruit membrane passes directly over into

the endosperm (*e*), and in the healthy one the gluten layer (Fig. 14 *k*)lies between the two tissues.

Investigations of such grains in the "imported" seed show a similar condition. The seeds seem malformed and the fact that the malformation manifests itself in the position of the embryo as well as in the development of the endosperm and especially in the thickened growth of the seed coat proves that this malformation must have been completed when the grain was forming in the head. Fertilization has nevertheless taken place normally since the embryo displays leaves and growing point as well as roots (the latter in increased numbers). But some local stimulus must at once have incited a cell increase in the fruit tissue and thereby displaced the embryo from the side towards the middle of the endosperm. This stimulus was active during the whole development of the seed and increased the vegetative activity so that the character of the endosperm underwent a change, for the vascular bundles are those of a vegetative axis. We observe a most important numerical increase of the cells in the tips of the seed, assuming the character of a vegetative axis and, by means of the entangled vascular bundles, resembling a stalk node. Abundant roots develop at these stalk nodes and it is not improbable that leaf buds might have begun had there been a greater aëration of the soil layers. We would then have had a case similar to that in dicotyledonous plants when, as has often been observed, vegetative axes develop from their fruit nodes.

For such processes, however, the seed lay too deep. There was no accessory apparatus for raising the seed to the upper surface of the soil, such as the elongation of the first internode in the seedling. As a result bacterial decomposition followed, due to the lack of oxygen, as was shown by the rancid smell of butyric acid.

This is the reason for mentioning the present case here. Had it been possible to determine exactly the causative fungus the case would have belonged under parasitic diseases. As it was impossible to make the mycelium fruit, the case becomes hypothetical as to the nature of the parasite. Only one thing is certain—viz., that the stimulating mycelium did not belong to the black fungi (Cladosporium, etc.). According to Brefeld's latest investigations on the penetration of the smut into the blossoms, it is highly probable that the smut spores, which have entered the blossom, germinate soon after the fertilization of the grain, and by the slow advance of their mycelia have exerted the stimulus on the seed coat.

3. Greater Horizontal Differences.

The individual development within the same plant species is influenced by horizontal changes in the place of cultivation from north to south, or east to west, as well as by the vertical elevation of the habitat. De Candolle[1] laid

[1] Sur la méthode de sommes de température appliquée aux phénomènes de végétation. Separatabzug der Bibliothèque universelle de Genève 1875.

down the principle that with approximately equal latitude and elevation, the temperatures above O° in shade are higher for the same developmental phase (time of blossoming, defoliation, etc.) in the western parts of Europe than in the eastern ones. Observations show that in Europe the length of the growth period decreases toward the northeast and increases towards the southwest. Because of the many mountain chains and plateau-like interruptions the phenomenon is less clearly evident in western Europe than on the great level plains of Russia. Kowalewski's[1] very remarkable work reports on this phase. This is based on the statements of 2200 agriculturalists scattered throughout all parts of European Russia, who had reported the time of sowing and harvesting of the grain. Since cultivation must be adapted to climatic conditions, the usual times for sowing and harvesting show the existing vegetative conditions.

The sowing of winter rye takes place in the southern part of the Government of Kherson on the 15th of September[2], at Archangel, on the first of August. The localities of simultaneous plantings of winter rye do not run parallel to the degrees of latitude, but are inclined from N. W. to S. E.; therefore, they run almost in the same direction as do the isocheims. The difference in the time of harvesting winter rye in the far north (Archangel) and in the south (Kherson) extends, like the time of sowing, over a month and a half. The seeding period for summer grain in the far north is one-third to one-fourth as long as at the southern limit. At the western it is two to two and a half times longer than at the eastern. The time of harvesting in the north is likewise one-third as long as in the south; in the west once and a half to twice as long as in the east. The localities of simultaneous ripening of summer grain run from S. W. to N. E., corresponding therefore in their direction with the isotheres.

The growth period in southern and southwestern Russia is only 85 to 110 days for rye, buckwheat, flax and barley,—but 110 to 125 days for summer wheat, millet, oats and peas. Sugar beets, maize and potatoes have the longest growth period,—150 to 165 days. Thus, in the south, the longest growth period is almost twice as long as is the shortest. On the other hand, in the north, the periods concerned are not only shorter everywhere but are also more simultaneous. In the far north and northeast the difference between the longest and the shortest growth periods does not exceed 10 to 20 days.

For the same cultivated plant, in European Russia, the rate of development increases on the average with the latitude. Thus, for example, oats in the Government of Kherson (south) have a growth period of 123 days, wheat and barley one of 110 days. In the north, however, (Archangel) the growth period of oats decreases to 98 days, that of wheat to 88 days, of bar-

[1] Kowalewski, W., Ueber die Dauer der Vegetationsperiode der Kulturpflanzen in ihrer Abhängigkeit von der geographischen Breite und Länge. Arb. d. St. Petersburger Naturforscherges., XV, 1884 (russisch), cit. Bot. Centralbl., 1884, No. 51, p. 367.

[2] All dates are given old style as still used in Russia.

ley to 98 days. In the same geographical latitude, a longer vegetation period is found in the west than in the east.

The causes of the shortening of the growth periods, therefore, cannot lie in the warmth which the plants receive at a corresponding degree of latitude, for otherwise the plants in the south would have passed through their development considerably more quickly than in the north, also since the southern black soil is raised to a higher temperature than the heavier, often clayey and damp soil of the north. Besides this, the lack of moisture in the south hastens maturity very greatly. Some other factor must therefore be determinative. Kowalewski states this to be *the length of the insolation.* He now assumes May 5th to be the mean time for sowing oats and August 20th as the mean time for harvesting them, finding thereby an insolation period of 2000 hours for the 98 days of vegetation in Archangel. If the period of bright nights be added to this, there is an increase amounting to 2240 hours. Kherson oats are sown on March 20, harvested on July 20th. In this 123 days of vegetation, however, only 1850 insolation hours obtain. Further, as Kowalewski says, it must be noted that the cultivated species of the north are adapted to a lesser degree of warmth. Therefore, when brought to the south, they ripen comparatively earlier. This result agrees with the one found by Schübeler[1] which will be mentioned later. Similar observations are said to have been made in Canada also.

In further explanation of the change in the length of vegetation, Kowalewski brings forward the greater intensity of illumination, the small cloud masses and the greater humidity of the atmosphere and, supported by Famintzin's investigations, he believes, for example, that the light optimum for assimilation is exceeded in the south and therefore has a retarding influence. This would correspond to the yellowing of the shade-loving plants, when grown in high mountains. It is not necessary to fall back upon the theory of the retarding action of the southern excess of light, if Wiesner's theory be accepted. In explaining the utilization of light on the part of plants in the far north, Wiesner[2] emphasizes, according to his investigations, the fact that in regions of the far north (Tromsö), with an equal elevation of the sun and an equal clouding of the sky, the chemical intensity of the daylight has been shown to be greater than in Vienna and Cairo, but less than in Buitenzorg in Java. The light factor of the far northern regions is distinguished in its illuminating quality by a relatively marked equability which obtains in no other locality where plants flourish. The plants of the arctic vegetative zone receive the greatest amount of light as a whole. Here, in the low growing plants there is no self-shading due to their own foliage, and even woody plants in adjacent southern regions show only a minimum amount of shade-producing branches.

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1 Schübeler, Die Pflanzenwelt Norwegens.

2 Wiesner, J., Beiträge zur Kenntnis des photo-chemischen Klimas im arktischen Gebiete. Sitz. Akad. d. Wiss. Wien CVII, cit. Bot. Jahresb. 1898, I, p. 586.

Wittmack has reviewed earlier cultural experiments as to the behavior of plants indigenous to any given locality when artifically introduced to a region farther south[1]. His conclusions follow;—plants from the north develop somewhat more slowly in middle Europe, catch up later with the indigenous ones, however, or even exceed them. It is evident, therefore, that the short growth period, which has become habitual in the north, is often still more shortened by the increased warmth of the southern habitat, provided also that the climate be dry. The damp climate of England with its low maximum temperatures retards ripening. The *humidity of the air* is a factor of great power and can delay ripening; just as, conversely, regions with great periods of drought, the climate of the steppes and similar conditions, not dependent on the degree of latitude, form limited centres where plants ripen prematurely. Too great drought certainly retards development, as has been determined experimentally. Stahl-Schöder's experiments, cited in the chapter on "Excess of Water," treat of soil dryness. The period of the influence of heat is very important and is indeed explicable. Heat in July and August is more advantageous than in May and June but the reverse is true for rain.

Wittmack's summary in general shows the significance of the physical structure of the soil in relation to the early ripening;—that the vegetative time in eastern regions is shorter for the same varieties of grain than in western ones.

Based on the observation that the varieties cultivated in northern climates retain their shorter growth period in the immediately following developmental periods, an active trade in northern seed has been developed. Meanwhile the quantity of the harvest should not be lost sight of. Abundant supply of nutrition being uniformly assumed, the quantity depends always on the length of the vegetative period,—i. e., the time of the formation of shoots. The longer time the grain has for the formation of vegetative organs (as in damp, cool seasons) the more abundant is the growth of shoots and with it the formation of a greater number of ears from the individual seeds.

If we should carry into the east varieties produced in the west, which are long-lived and characterized by great productivity, we would run the risk of frosts. This is most strikingly true in the English varieties of wheat, from the squarehead group, which toward the east come less and less true to seed, because they winter kill. Experience shows in regard to frost-resistance, that seeds from northern regions give plants in southern latitudes which at times not only ripen earlier, in spite of an initial retardation, but also better withstand frost.

From the result of Schübeler's[2] observations, it should be emphasized, that the quick growth, which has become habitual in northern or Alpine

[1] Ueber vergleichende Kulturen mit nordischem Getreide, Von Dreisch, Körnicke, Kraus, Vilmorin and others, referred to by Wittmack. Landwirthsch. Jahrb. 1875, p. 479, and 1876, pp. 613 ff.

[2] Schübeler, Die Pflanzenwelt Norwegens, 1873, pp. 77 ff.

climates because of a short vegetative period, is lost after four or five years of cultivation in lower latitudes. Conversely, long-lived varieties accustom themselves in a few years to a short vegetative period. Yellow chicken maize from Hohenheim, for example, which ripened in 1852 at Christiana in 120 days after repeated sowings, shortened its growth period to the extent of 30 days in 1857. In Christiana the developmental period of barley is 90 days, but seed brought from Alten (the 70th parallel) needed only 55 days (see Kowalewski).

Of the chemical properties developed in a northern habitat, which in great measure correspond to the changes in plants in high elevations, the fact that the sugar content of the fruits decreases toward the north while the aroma increases is of especial importance. Bonnier and Flahault maintain also that not only the size of the leaves increases in the darkness of the north but also their green color[1]. Schübeler's experiments in summary[2] give the following special examples:—In wheat brought from Ohio and Bessarabia, the grain became darker in color each year until it was as yellow brown as the native Norwegian winter wheat. Similar results were obtained with maize, beans, peas, celery, etc. Celery taken from a region extending from the Caucasus to Hindustan, grows in Africa (Egypt, Abyssinia and Algeria) and may be found in Europe from the Mediterranean to the Baltic; it now extends even into Finland up to the 69th parallel. There, however, the root stalks are poorly developed;—the aroma, nevertheless, becoming more pungent[3]. The greater intensity of color in the blossoms, as already mentioned, a peculiarity shown to correspond with an increasing elevation above sea-level, also appears in most garden flowers as cultivation advances towards the north. In regard to the formation of aromatic substances, besides celery, juniper may also be cited as an example. In Norway it is much richer in oil than in Central Europe. Onions also and garlic are uncommonly pungent in Norway. Strawberries are sour but aromatic, while, according to Götze, they are exceedingly sweet in Coimora, but almost without any aroma. Plums often remain so sour that, compared with fruit brought from more southerly regions, they still seem immature. A similar condition exists with grapes as shown by comparing the sweet Portugese grape with the less sweet but aromatic Rhenish grape.

In considering the horizontal differences, expressed in the decrease of rainfall and increase of clearness of the air, from the west towards the east, in the conditions of light between southern and northern regions etc., we should not forget one circumstance, to which de Candolle[4] has already called attention. This, to be sure, has not been sufficiently verified experi-

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1 Bonnier et Flahault, Observations sur les modifications des végétaux suivant les conditions physiques du milieu. Annal. d. sc. nat. Botanique, t. VII, Paris 1879, p. 93.

2 The effects of Uninterrupted Sunlight on Plants. Gard. Chron. 1880, I. p. 272.

3 Hansen, C., Der Sellerie. Gartenflora, 1902, p. 18.

4 de Candolle, A., Sur la méthode des sommes de température appliquée aux phénomènes de la végétation. Archiv. des sc. physiques, etc. Nouv. ser. LIII. LIV. Genf 1875, cit. Bot. Jahresber. 1875, p. 585.

mentally, but finds repeated substantiation in practical experience. It is namely the greater, *more complete dormant period* of plants. According to Ihne[1], trees which thrive normally in Central Europe and in Coimbra put out their leaves possibly a month earlier in Coimbra and their autumnal change of color occurs about a week and a half later than with us. Thus their dormant period is about six weeks shorter there. The length and completeness of this dormant period, however, must influence greatly the rate of subsequent development. It may indeed be assumed that, with the continuation of a temperature which does not stop the functions entirely, a number of vegetative processes continue with a slow but steady consumption of materials (process of oxidation) and without any compensation to the plant through newly assimilated substances. Besides this, it seems that many enzymes, which affect the energy of metabolism, either succeed in developing to the necessary amount only during a complete dormant period, or are made ready for it. If no complete rest takes place it may be observed especially in the two or three year old bushes and in the buds on branches of woody plants. These are forced earlier and produce weaker organs (smaller leaves, a greater number of sterile blossoms).

The increased weight of the seeds in northern latitudes has already been considered. There are, however, some experiments by Petermann[2] which prove *a higher germinating power* of Swedish seeds of clover varieties, timothy *(Phleum pratense* L.*)*, and of spruces and pines as compared with German, French and Belgian seeds. The Swedish seeds, which actually, on an average, possess a greater weight, show greater power of germination, not only in the number of fertile seeds which can germinate, but also in the energy with which germination takes place. These results may be explained very well by a greater developmental energy in the plants, due to a more complete winter rest.

These observations have a very noteworthy practical bearing in so far as they affect the culture of seeds obtained in exchange. It is not enough merely to introduce seed from other regions, but it will seem necessary to ask above all, what characteristics it is desired to improve in the cultivated plant and in what climates these characteristics attain a higher development. Taken from such localities the seed will then give the desired results.

The cultural results, obtained by using plants of other climates, hold good as a rule, however, only for a very few growth periods. Often the influence of the present habitat is felt in the second generation when the plants of foreign importation have assumed the habits of the native varieties. Fruit trees taken from Angers grew and bloomed on Malorka even at the end of February, while the native ones did not blossom until a month later[3]. A shipment made two years later from Angers showed the same phenom-

[1] Ihne, Phänologische Mitteilungen. Cit. Bot. Jahresb. 1898, II, p. 409.
[2] Petermann, Recherches sur les graines originaires des hautes latitudes. Extrait du t. XXVIII. des Mémoires couronnés et autres Mémoires publiés par l'Acad. Royale de Belgique, Bruxelles, 1877.
[3] Gartenzeitung von Wittmack, 1882, p. 374.

enon. The fruit trees of the first shipment were now, however, blossoming later, i. e., simultaneously with the native ones. The transition from the hereditary form of growth to the new one determined by the climatic conditions is rarely effected as rapidly as it is lost when returned to its former habitat. Yet, in our vegetables, we have examples of a rapid change in pecularities. In a tropical climate these keep approximately their own character only in the first year. Already in the second year the seeds of these imported plants produce elongated, lignified specimens[1]. These are our cultivated forms which are beginning to vary from the normal. No rapid changes are noticeable in species growing wild, as has been shown by Hoffmann's experiments with parallel seeding of certain forms of Phaseolus and Triticum in Giessen, Genoa, Montpelier, Portici and Palermo[2]. On the other hand, Hoffmann mentions slow changes, first taking place in the course of many generations. Thus *Ricinus communis* becomes tree-like and perennial in the tropics, in the same way *Reseda odorata* becomes more or less persistent in New Zealand and, conversely, *Bellis perennis* becomes an annual in St. Petersburg.

Among the changes in mode of growth, which are only slowly completed, belongs the formation of the annual rings in our trees. At any rate the distribution of vascular spring wood and the slightly vascular summer wood within the same degree of latitude fluctuates in each year according to the amount and distribution of precipitation. But in the changes of the average weather, due to changes in latitude, the same differences become constant and form thereby ecological varieties. Bonnier[3] treats thoroughly such anatomical differences in the development of the same species in northern and southern positions. He compares examples of the linden, red beech, acacia and others from the region of Toulon (with its 260 days of active growth) with those at Fontainebleau (growth period 178 days) and found that the spring wood develops better in the south, having more abundant, often wider ducts. In this the abundance of precipitation in the spring in the Mediterranean district surely has a definite bearing. The summer wood of the south, however, is richer in libriform fibres and often consists only of these, while at Fontainebleau numerous ducts are formed, even in summer. The leaves of the Toulon plants were shown to be one-third to one-half thicker and provided with more layers of palisade parenchyma in comparison with the plants grown in the north. The stomata are more numerous, the sclerenchyma is greater and the cuticle strengthened. The Toulon plants exhibit the character of Mediterranean flora in general.

The greater intensity of the color of the blossoms, as the plants advance from the plains to the mountains and from lower latitudes to northern

1 Deutsche Gärtnerzeitung, 1883, No. 17.

2 Hoffman, H., Rückblick auf meine Variationsversuche von 1855 bis 1880. Bot. Z., 1881, p. 430.

3 Bonnier, Cultures expérimentales dans la région méditerranéenne, etc. Cit. Bot. Jahresb. 1902, II, p. 299.

regions, has already been considered. Recently attention has also been directed to the increased change of color in foliage leaves and its peculiar significance as a protective adaptation has been suggested. MacMillan[1] treats of these conditions very fully. He speaks of *"warming-up colors"* meaning especially the red coloring substances which are more abundantly represented in colder regions. Alpine and arctic plants are more often found with blue or violet blossoms than with yellow; the ends of the twigs are often reddened. The temperature is somewhat raised by the *red coloring matter* and the influence of cold somewhat weakened. If one thermometer be covered with a green leaf and another with a purple one, while both are exposed to the sun, in a short time the thermometer protected by the purple leaf shows a rise of 6° to 10° of temperature. In the same way he found that a thermometer, stuck in a bunch of violets, shows a higher temperature than one in a bunch of cowslips, after an equal exposure to the sun.

The *autumnal coloring* may be conceived as a definite reaction of the plant to the lowered temperature. The plant provides warmth for itself in its red coloring matter. On this account so many spring flowers are red and violet and autumn flowers blue or red.

In warm climates plants often assume peculiarities directly opposite to those of arctic or alpine plants. In tropical plants the storage cells are less strongly developed than in related species from colder regions. The buds are less protected, pubescent coverings more rare on leaves and twigs (with the exception of desert plants). Many winter habits disappear. There are fewer biennials. The warming-up colors recede more and more, while white, yellow and spotted blossoms (Orchids) predominate.

Nature would develop red coloring matter to prevent loss of the superfluous light and to transform it into warmth and to use it as a stimulus to growth.

We cannot support this theory of the premeditated utility of the red coloring matter as an apparatus, producing warmth and weakening the light, even if we had such an inclination. If the red coloring matter has once been produced, it will be effective in the way given. The idea that the plant can produce it as a protection against cold, when the temperature becomes lower, is not plausible, because in the hottest summer temperature leaves can be reddened. In the Rosaceae which are rich in tannin (Crataegus, for example), I have been able to produce the red autumnal coloring after a few weeks in the middle of summer by girdling the twigs. The fact that in summer the underside of many leaves, when reversed, becomes red within a few days is universally known. Parasites furnish further instances. On the same cherry tree, for example, the leaves of branches attacked by *Exoacus Cerasi* turn glowing red, while the healthy ones remain green. In many spot diseases the circular fungus centre appears surrounded by red. Amaryllidaceae, whose leaves die down in summer (Hippeastrum etc.), develop carmine spots and stripes.

[1] MacMillan, Conway, Minnesota Plant Life Saint Paul, Minnesota, 1899, p. 417.

Thus we believe that the red coloring matter may be looked upon as a necessary reaction of the cell to the influence of different factors connected with a relatively over-abundant supply of light. One of these factors may be the lowering of the temperature due to a change in the latitude or longitude of the place of growth.

If we look back to the many changes undergone by the plants in their morphological and chemical structure because of any change in latitude of the place of growth, we cannot shut our eyes to the conviction, that *not infrequently in these changes of place may be sought the reason for a predisposition toward disease or, on the other hand, toward greater immunity.*

We have mentioned that the western squarehead wheat grown in eastern regions has greater susceptibility to frost and now remind the reader that parasitic diseases may also be dependent on the different mode of development of the host plant inherited in the seed. One should consider, for example, the fact that many parasitic fungi appear or are especially abundant at definite periods. In case such fungi only attack young leaves, the presence of young leaves when the spores are ripening will determine an epidemic. The rapidity with which a plant passes through its developmental cycle in any given climate is a determining factor in this question. If it develops slowly, its leaves are young and remain susceptible for a longer time, giving a greater danger of fungus infection. If a variety matures quickly (for example, one introduced from more northern or eastern regions) then the leaf may be fully matured at the time of the actual distribution of the spores and therefore be resistent to many parasites.

Such circumstances deserve greater consideration than has been given them as yet. They will also be a factor in the discussion of the *"biological races"* of individual parasites, for it is most probable that often infections of the most closely related host species fail because the host plant at the time of infection is already in an advanced developmental stage, in which the leaf is more mature, i. e., has thicker walls and less cell-content. The fact that the fungus infection is connected with a definite developmental stage of the host plant is shown, for example, in the rust fungi of grains. Eriksson[1] states that the rust occurs earlier in the varieties ripening early and recent observations show that the different forms of Puccinia have definite periods for attacking grain. Thus it was shown in 1904[2] that *Puccinia glumarum* appeared first and foremost in wheat, then followed *P. dispersa* which, however, attacked only those organs and varieties which were still immature. Later, slowly ripening varieties of wheat were found badly attacked by *P. dispera* and slightly by *P. glumarum,* while the converse is true for varieties maturing early. *P. graminis* was found in stored grain.

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[1] Eriksson, J., Sur l'origine et la propagation de la rouille des céréales par la semence. Ann. scienc. nat. Bot. VIII. sér. Vols. XIV. and XV. Paris 1902.

[2] Jahresb. d. Sonderausschusses f. Pflanzenschutz. Deutsche Landw. Ges. 1905 Getreiderost.

Glassy Grain Kernels.

These must also be considered as the result of climate influences.

Grains are called glassy when their endosperm is hard, almost translucent and grey or reddish in cross-section, while in the normal mealy kernel the endosperm appears soft, white, porose and easily friable.

This glassiness of the kernels occurs usually more abundantly in the north and east of Europe than in the west, which fact points to the influence of atmospheric dryness with a higher light intensity. In damper, western regions the vegetative organs obtain a greater ascendancy. Thus Liebenberg[1] states, for example, that the otherwise excellent northern barley has two disadvantages;—viz., too large a percentage of glassy grains and too dark a color which is caused by rain falling on the grain when ready for harvesting. These gusts of rain at harvest time naturally play no part in the development of grains which mature during the dry season. With the lengthened light action, varieties of rye also become intensively colored. The same author reports that at the grain exhibition in Sweden, the oat samples, on an average, possessed only 22.66 to 32.04 per cent. of chaff by weight, while in the Austrian and French varieties it fluctuated between 25.23 and 38.37 per cent. In general there is truth in Haberlandt's[2] statement, that a continental climate produces glassy grains, but that, on the other hand, cool, wet summers or an artificial abundance of nutritive substances and water produce mealy, specifically lighter grain kernels, poorer in nitrogen.

The glassy condition of the grain, according to Grönlund's[3] investigations on mealy and glassy barley, exists in the fact that the cells of the albumen in the mealy grain which contain the starch show that the spaces between the starch cells are filled with cell-sap, while in the glassy grains these spaces are filled with protoplasm. Johannsen's[4] work assumes a greater air content not only between the walls of the mealy grains, but in their whole mass. In germination, the glassy grains become mealy. According to Grönlund, who, moreover, acknowledges no relation between weather and the production of the glassy conditions, glassy kernels germinate more easily and better and give stronger plants. Although he assumes as incontestible that glassy kernels may be produced from soil containing much nitrogen, yet he believes that poorer, sandier soil, poorly cultivated, produces this peculiar formation much more certainly. He found that mealy grain was produced by pure *potassium fertilization.* Moreover, both forms occur at times in different stages in the same head. I would like to assume for the production of glassy kernels that the process of starch formation is

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[1] v. Liebenberg, Bericht über die allgemeine nordische Samenausstellung etc., 1882, cit. Bot. Centralbl., 1882, No. 43, p. 115.

[2] Haberlandt, Die Abhängigkeit der Ernten von der Gröfse und Verteilung der Niederschläge. Oesterr. landw. Wochenbl., 1875, p. 352.

[3] Nach einer Preisscheift des Verf. cit. im Jahresbericht f. Agriculturchemie XXIII (1880), p. 214.

[4] Allg. Brauer- und Hopfenzeitung, 1884, Nos. 78 and 79.

shortened in sandy soil, which dries quickly, and, since potassium makes the corn mealy, I would much sooner believe that the action of the potassium is stopped too soon and indeed because other processes, viz., those of ripening, take place too early and too intensively. This will happen much more quickly with strong action of light and warmth and when the water content is less. Sanio's[1] statement that in East Prussia the glassiness of wheat is due to its becoming overripe on the stalk supports the theory of the predominance of the ripening process at a time when starch formation should be taking place. This opinion is analytically supported by R. Pott's investigations[2] who found on an average a higher percentage of ash in glassy varieties of wheat than in mealy kernels. The kernels, in the too rapid ripening, had not completely consumed the mineral substances in forming organic substances. Compare here the high percentage of nitrogen in the grains of oats plants, which suffered from a scarcity of water or from its excess (see chapter, "Excess of Water").

Petri and Johannsen[3] have made investigations which throw much light on the nature of glassy kernels. The former, as early as 1870, stated that glassy kernels, when softened by water, become mealy and the latter substantiated this observation. Two hundred kilos of barley were moistened with half that amount of water, until they had taken up 15 per cent. They were then dried immediately, spread and turned until the original weight was again obtained. The percentage of mealy kernels now was 50 per cent., while in the original material it amounted to only 19 per cent. In cultural experiments it was found that, in early seeding, a mealier barley, poorer in nitrogen, had been formed, while in later sowing the harvested product was richer in nitrogen. This discovery indicates that in this glassiness of the kernels there is only a mechanical difference, which develops if ripening is very much hastened by a scarcity of water with an excess of light and warmth. A gradual ripening process gives a longer time for developing an increased starch content with the retention of a larger water content in the substance which is later partially replaced by air. This refers especially to the protoplasm in the endosperm cells. The starch grains lie embedded in this. With quick ripening, the cytoplasm sticks close to the starch grains, making the kernels appear glassy. With slower ripening and greater water content the cell is more loosely constructed, while between the starch grains more cell sap and later more air are present, and then, because of the larger intercellular air spaces, the grain is opaque and mealy. As the protoplasm predominates, the tendency is toward glassiness, and on this account, even normally, the outer layers of the seed, as, for example, in maize, are glassy, the inner ones mealy. These conditions explain Schindler's observations[4] that, in wheat grains, mealy and glassy portions can alternate.

[1] Botanisches Centralbl., 1880, p. 310.
[2] Jahresbericht f. Agriculturchemie 1870-72, II, p. 5.
[3] Johannsen, Bemerkungen über mehlige und glasige Gerste (Ugeskrift for Landsmaend), 1887, cit. Biederm, Centralbl., 1888, p. 551.
[4] Schindler, Lehre vom Pflanzenbau auf physiologischer Grundlage. Wien 1896.

The above explanation of the production of glassiness is substantiated by the experimental results, which have been obtained by the Deutsche Landwirtschafts-Gesellschaft[1]. The report states:—The glassiness of the kernels depends more on the conditions of growth than on the variety. Varieties with a *shorter* vegetative period are glassier—such as Lupitzer, Strube's bearded and Galician club wheat in comparison to Schlanstedter and Noe wheat. The productive power of the varieties in general stands in inverse relaton to the glassiness of the grains.

4. Continental and Marine Climates.

The characteristic distinction of regions influenced by the ocean consists in the lesser fluctuation between summer and winter temperatures,—since the summers are longer and cooler, the winters warmer. We find that, under the influence of the Atlantic Ocean, spring comes earlier, while autumn is delayed longer than in regions with a continental climate. Yet the effect on vegetation is not the one expected, in spite of the earlier spring, for the blossoming time of wooded plants is at most only a few weeks earlier, because of a cooler spring temperature and the ripening of the fruit is scarcely earlier, indeed, it is often delayed and occasionally does not take place at all. Consider, for example, grapes which do not ripen out of doors in England. Throughout the year, the air is more moist and in the change of season extensive heavy mists often prevail.

Haberlandt's opinion has already been mentioned, according to which early maturity of plants may appear with the same ease in northern latitudes as in southern ones, and thus lead to the production of corresponding varieties. Conditions of humidity also act determinatively in this and all become evident in the great fluctuations in a continental climate in contrast to an uniformly damp coast climate. Haberlandt's culture experiments[2] gave results as follows. Seed brought from damp climates gives proportionately more straw, but less grain,—the grain is also more easily subject to lodging. On the other hand, in seed from dry regions, with a short spring and hot, dry summer, there is a production of less straw and greater grain crops, and plants from such seed better withstand *drought.* When exchanging seed it is more advantageous to take it from countries with a continental climate. The hard winters influence the grain product in such a way that the plants produced are less apt to winter kill than those which have been transplanted to the East from the moister west with its milder climate.

The continental climate produces smaller but specifically heavier grain, while a cool and damp summer or an artificial abundant supply of water and food substances increases the size of the grain, to be sure, but at the same time causes more porous contents, since, instead of the glassy con-

[1] Mitteilungen der Saatzuchtstelle über wichtige Sortenversuche. Saatliste vom 6. Dez. 1914. Deutsche Landwirtsch.-Ges.

[2] Haberlandt, Fr., Ueber die Akklimatisation und den Samenwechsel. Oesterr. landw. Wochenbl., 1875. No. 1.

dition, a mealy one appears, together with a decreasing specific weight and decreasing nitrogen content.

Finally an important observation bearing on the exchange of seed is the fact that winter grain coming from regions above the 45th parallel of latitude and cultivated by us in the spring, does not produce shoots, while on the other hand, that taken from lower latitudes behaved with us like summer grain.

Because of the great interest on all sides in the colonies, it is necessary to take tropical conditions into consideration. Here the differences of temperature on the land and between land and sea attain a greater significance. Thus, for example, Fesca[1] reports, in regard to the great warming of the land in direct sunlight as compared with that of the sea, that the temperature of the tropical ocean rarely exceeds 30°C. while the rock is heated up to 60° to 70°C. Pechuel-Loesche observed a soil temperature above 75°C. on the west coast of Africa in the 5th parallel of south latitude, not less than 36 times between January 1st and March 4th. In contrast to this, however, stands the nightly cooling down to 15°C. and less. Daily fluctuations of the soil temperature from 30° to 40°C. are very frequent in the tropics while, on the other hand, the daily fluctuations of the sea might at most reach 1°C.

As a result of the differences in the morning quality of land and sea, a low barometric pressure must be produced on land in the day with the intensive sunlight, so that the air from the sea streams in that direction and, conversely at night. These sea and land breezes are considerably more intensive in the tropics and sub-tropics with the stronger contrasts in warming land and water and form a factor to be reckoned with. According to Saito[2] the air above the sea is almost free from mould fungi, bacteria and yeast germs, while the air above the land (street and garden air in Tokyo was investigated) was especially rich in germs in wet and warm periods. Thus the sea breezes act as purifiers of the air. The sea breezes decrease towards the poles, since the sea gradually assumes a higher mean heat than the land and also because the daily fluctuations of the soil are less.

For the same reason the changing annual winds, the monsoons, correspond to the periodic daily winds in the strong warming of the great continents to which vegetation must adapt itself.

The amount of precipitation occurring as rain depends also on the relation to the sea and the temperature and, accordingly, it is most abundant in a warm sea climate, scantiest in a continental one. An annual mean of 9°C. approximately holds for all the German North Sea coasts. With an 80 per cent. saturation, the air would contain 7.26 g. water vapor in a cubic meter. If the air cools down to 4°C. it can hold only 6.9 g. water vapor per cubic meter and the difference must therefore be eliminated as precipitation.

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[1] Pflanzenbau in den Tropen und Subtropen, p. 23.

[2] Saito, Untersuchungen über die Atmosphärischen Pilzkeime. Journ. College of Science, Tokyo. Vol. XVIII.

If tropic air reaches 25°C. with the same saturation (80 per cent.) it contains 18.48 g. water vapor and eliminates 1.18 g. water per cubic meter when cooled down to 5°C. This amount of precipitation therefore is more than three times that of air at 9°C. when influenced by the same decrease in temperature on the North Sea coasts. Thus are explained the heavy tropic rains and especially the *heavy fall of dew* which, in places, must suffice for a certain period in hot climates as the only source of water.

Just as in cultivation experiments, soil analyses and mean temperature offer no sufficient insight into a possible utilization of food substances on the part of cultivated plants, just so little can the annual rain fall indicate the moisture conditions of a region. For it depends essentially upon the soil conditions and the distribution of the precipitation in the different months. Over a greater part of the desert of Sahara (see Fesca) the same or a greater amount of rain falls than that sufficient for Germany's agriculture (60 cm.) without its having there any essential effect. For, on a highly heated soil, moisture exaporates immediately. The most desirable distribution of rain in the tropics is not the one extending uniformly throughout the whole year, but, viz., at the beginning of the vegetative period an abundant precipitation and then a time of dryness. The abundant clouds in the rainy season contribute essentially to the production of a cooler temperature which is especially favorable for the development of the vegetative organs.

Along the coast the climate is cloudier than it is inland. In regions of great atmospheric dryness, as in the Mediterranean basin, often there is only 20 per cent. cloudiness as an annual average: in the dryest months often only 10 per cent.,—in the moist tropics not infrequently more than 80 per cent. Since, however, the cloudiness decreases the taking up and giving off of heat, the temperature of the lower latitudes is less and that of the higher, greater. Many cultivated plants require these lower temperatures and cloudiness. We believe, with Zimmerman[1], that many diseases in coffee plantations, especially the excessive production of fruit, may be due to insufficient shading. In the same way it may be that the great susceptibility to fungous diseases which has appeared in the last 15 years[2] since tea has been cultivated in the Caucasus, has been due in part to the difference of the Caucasian climate from that of the regions from which tea was introduced.

The development of the plant body is of course adaptable to the climatic conditions and factors of growth. The more recent biology takes these circumstances into consideration as is shown by the work of Hansgirg[3]. He speaks of stenophyllus wind leaves (as in the willow type); of leather (coriaceous) and wind leaves (palm type); of xerophyllus leather leaves (Myrtus, Laurus), of dew leaf types (Bromeliaceae, Pandaneae); thick

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[1] Zimmermann, Sonderberichte über Land- und Forstwirtschaft in Deutsch-Ostafrika. Vol. I, Part 5, 1903.

[2] Speschnew, Travaux du jardin bot. de Tiflis VII, 1 Verhandl. d. Internat. landwirtsch. Congresses in Rom 1903.

[3] Hansgirg, A., Phyllobiologie nebst Uebersicht der biologischen Blatttypen etc. Leipzig, Bornträger, 1903.

leaves (Crassula and mesembryanthemum types) etc. The most conspicuous example is the vegetation of the sea shore with its halophytic character. Brick[1] explains the fleshy and glassy constitution of the vegetative organs as due to the abundance of sodium salts, which makes the parenchyma extremely turgid.

The greater the number of examples showing the adaptation of the plant to climatic conditions, the more marked will be the untenability of the theory, that the *climatic relations* formed in each place of cultivation can be changed at will without causing injury. If the whole sum of the climatic factors should correspond in two widely separated localities this would be no guarantee that the given plant would thrive as well in the new home as in the old, since the distribution of light, heat and moisture can be proved to be very different in the different periods of growth. The diseases of the New Holland and Cape plants which, adapted to a dry climate, must pass their lives in our sunless, damp conservatories, give the most abundant proof. Decay of stem and root, dying of the twigs caused by Botrytis etc., constantly cause injuries to the successful cultivation of these plants. The so-called damping off of the shoots of Pimelea, Chorizema, Pulteneae, Correa, Boronia, Agathosma, and Borosma, of Helichrysum, Humea etc., is a result of the great humidity in our conservatories which can not be overcome.

5. Influence of Forests.

The forestration of a locality modifies the influences of the position and soil constitution and to this point pathology must pay especial attention. The influence of forests is like that of surfaces of water, for, since organic substances possess a higher specific warmth than do mineral substances, the overgrown soil will be cooler, with an equal exposure to the sun, than the naked rock or sand. The summer heat is also moderated by forests. With the abundant evaporation of the foliage, the air becomes more moist, the thicker the growth and the less motion in the air. Corresponding to the greater evaporation, there is a more abundant cloud formation over forests which is not so easily dispersed. Since the relative humidity of the air is greater in and above the forest, much more dew is formed. The force of the rain gusts is decreased. Since torrential rains, especially on slopes, cannot be taken up as quickly, the mass of water runs off from the naked earth and at the same time carries away the fine humus from the higher fields to the lowlands. The annual repetition of this process so changes the conditions of the fields that the higher places become impoverished and retain only a slightly fertile soil skeleton, while on the low lands the humus layers keep on growing. The power of the soil to retain water decreases with the loss of humus and injuries due to a scarcity of water show themselves. In heavy soils the steady beating of the rain drops in severe storms tends to form a crust.

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1 Brick, Beiträge zur Biologie und vergleichenden Anatomie der baltischen Strandpflanzen. Cit. Bot. Jahresb. 1888, I, p. 765.

All these unfavorable conditions are overcome by the forest, the tops of the trees catching the rain and partially retaining it. Nevertheless the water, which passes through and runs down along the trunks, is retained by the moss and the dry leaves in deciduous forests, forming the upper surface of the soil or the humus, thus becoming of benefit to the vegetation. Furst's[1] "Illustriertes Forst- und Jagdlexikon" gives some positive figures on these theoretical discussions. Based on the observations of the forest meteorological stations, it is stated that the temperature of the air in the annual average is possibly 0.8°C. lower under the close roof of tree crowns of the forests, than in the open. The difference is greatest in summer (up to 3°C.) while it approximates the annual average in spring and autumn and almost disappears in winter. "The fluctuations in temperature are less under the shelter of the tree crowns than in the open."

The temperature of the forest soil is from 1 to 3°C. lower at all seasons of the year than that of open land. The absolute moisture does not differ in the forest and in the open; but, on account of the lower temperature, the relative moisture in the forest during the winter, spring and autumn is from 4 to 8 per cent. higher than in the open, and in summer from 12 to 20 per cent. The evaporation from a free surface of water in the forest is from 50 to 60 per cent. less than in the open; "the evaporation of the water from the soil is reduced from 80 to 90 per cent." Of the precipitated moisture, 10 to 50 per cent. will be retained by the crowns of the trees, according to the species, the age and dimensions of the forests as well as the amount of precipitation, and in light rains it often amounts to 100 per cent. In general 60 to 80 per cent. reaches the soil in the forest. "In Central Europe the annual and the summer temperature will be lowered 1° and 2° to 3°C. by the dimensions of the forest and the relative moisture raised ca. 5 per cent. and 15 per cent."

Since the amount of the distant action from extended forestration has not yet been determined, the question as to the influence of the forest on climate must remain open. But one effect of the forest on the immediate vicinity cannot be denied and this phytopathologists must consider.

Differences in insolation are felt slightly in the forest, but very quickly and strongly in the open field. The soil is warmer; the layers of the air lying above it must necessarily produce an equalizing air current which is most significant in spring when vegetation awakens.

Hesselmann's[2] investigations give an insight into forest vegetation. He observed the regular dying of the twigs which takes place within the crowns of the trees and found that in birch and mountain ash the leaves were still strongly active in assimilation; but in the hazle-nut markedly less so. If well-lighted branches die, phenomena of correlation are at fault. Trees which can live in shade develop distinct sun and shade leaves; trees

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[1] Illustriertes Forst-und Jagdlexikon, 2nd. Ed., revised by Dr. Hermann Fürst, Berlin 1904, Paul Parey, p. 384.

[2] Hesselmann Hendrik, Xur Kenntnis des Pflanzenlebens schwedischer Laubwiesen. Jena, Fischer, 1904. Cit. Bot. Centralbl. v. Lotsy, 1904. No. 49.

which require light do not show this difference. The assimilation activity of the flora of the forest floor is very rapid in spring when the trees and trunks are still bare and decreases with the foliation more slowly in shade trees, because of their structure, until it finally ceases entirely. The respiratory intensity decreases with the decreased "food consumption." Detached shade leaves of *Convallaria majalis* etc., form more starch in the sun as well as in the shade than do sun leaves treated in exactly the same way and they also fix carbon dioxid more rapidly in the same amount of light than do these. Moreover in Convallaria the storage of starch was found to be less, the drier the soil. Equally large leaf surfaces containing palisade cells transpire much more strongly than do those leaves having the structure of shade leaves.

It is evident from these statements that changes of great importance must take place in the economy of trees accustomed to shade, when suddenly exposed to light, viz., when left standing by removing parts of forests. In parks too strong and sudden an exposure to light by the removal of numerous trees not infrequently results in the partial or total death of the crowns of the specimens left standing.

We must turn our attention to still another point. If plantations of fruit trees along streets on level land, especially cherries, be examined, many cases will be found wih trunks split open on the south or southwest side, with the bark torn into tatters and often showing lumps of gum on the wounded surfaces. These injuries are very evidently due to frost. The explanation lies in the fact that the level, cleared lands are exposed in spring to extreme temperatures. The February and March sun shining intensely on the trunks, and strengthened in its action by the reflection from the soil, starts the reserve plant food prematurely and the tissues, being richer in water and sugar, at once succumb to the action of the frost. A moister atmosphere in the neighborhood of water or wooded areas equalizes the temperature and serves as a protection from frost.

Naturally in regions with greater soil elevations and more noticeable differences between valleys and mountains these factors co-operate determinatively and often decisively, but on the plains the forestration is a very considerable factor. Cutting considerable forest tracts on wide plains often is a source of injury avenged not only on the owner but on the whole neighborhood, since it increases the chance for damage from *late frosts.* In this connection many small forest tracts, scattered over a large plain, would be of use since no considerable distant action from one single large forest may be reckoned upon. There is a further advantage to be derived from forests,—that of *protection against the wind (windbreak)* when there are no mountains.

Just as every bright side has its shadow, forests can exert an injurious influence on the adjacent fields. The forest properly located can withhold the summer rains, usually coming from the west, from a given field so that there will be dry, windless streaks across the fields in its immediate prox-

imity,—or, on the other hand, the forest may make streaks across the field accessible to rains and prevent the rapid drying off of the seeds. In the first case, the forest may become a harboring place for injurious insects. It has often been observed in the case of dwarf cicades that they begin their devastation of the fields from the dry edges of the forest. The more severe attacks of Puccinia, Ophiobolus and *Leptosphaeria herpotrichoides* serve as examples of the influence of moisture, near the border of the forest, upon fungous diseases. Goethe's discoveries[1] as to the influence of the place of growth upon the canker of fruit trees, caused by *Nectria ditissima,* must be considered. The tendency to disease from canker is favored by an increased humidity as offered by higher regions or also by cold valley soils. "The trees show in such places a meagre growth and are covered with mosses and lichens. Similar conditions are observed also near extensive forests, out of which cold, damp air streams even in the summer."

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1 Goethe, Rudolph, Ueber den Krebs der Obstbäume. Berlin 1904. Paul Parey.

CHAPTER II.

UNFAVORABLE PHYSICAL CONSTITUTION OF THE SOIL.

I. LIMITED SOIL MASS.

Root Curvature.

For practical agricultural and forestry purposes, the question as to the limitation of space in the soil plays a subordinate *rôle* when there is no scarcity of food stuffs, since disturbances in nutrition, arising from the overgrowth and rubbing of roots pressed tightly against one another, or by their growth in crevices of rocks, have no agricultural significance. The matter is quite different, however, in gardening and the cultivation of house-plants by the plant lover.

In these circles, however, opinions as to the influence of too small soil space on the spreading of the roots are divided. Predominant and also clearly expressed on the part of many agricultural chemists is the opinion that the mechancial effect on roots, closely pressed on one another and tangled by repeated curvature, has no influence on the thriving of the plants. They think that in limited soil space only a scarcity of food may ever be involved which would make itself felt very quickly and could be corrected advantageously by fertilizing. The best proof should lie in the cultivation of the so-called *"market varieties"* by commercial growers in large cities, who, conforming to public taste, grow very vigorous specimens of all blossoming plants (Fuchsias, Pelargoniums, Begonias, etc.) in relatively very small pots.

The fact is correct, the explanation, however, inconclusive.

The restriction of a large root mass in a small space results first in the increased production of lateral roots. This may be observed easily in water cultures. If one of the large roots reaches the bottom of the glass container and its tip is forced to bend around, new lateral roots are produced immediately. Noll[1] has given special study to this. He found that on the bent portions of the main root, the lateral roots were formed only on the con-

[1] Noll, F., Ueber den bestimmenden Einfluss der Wurzelkrümmungen auf Enststehung und Anordnung der Seitenwurzeln. Landwirtsch, Jahrbücher XXIX (1900). p. 361.

vex surface, the concave surface remained free. This is true of both main and lateral roots and not only under mechanical influences, but also as a result of geotropic and hydrotropic stimuli. Pollock[1] has pointed out, in this connection, that twisted roots contain more water in the cells of the convex side than in those of the concave side.

Noll ascribes this growth of new lateral roots at the point of curvature to a perceptive power of the plant to the formal relations of its own body *(Morphaesthesia)*. This expression may be accepted if by it is understood a mechanical transfer of material resulting from the stimulus of curvature on the affected tissues. The process is similar to the one occurring after direct injury when the cytoplasm has accumulated in the cells adjacent to the wounded surface. Of course laterals are found also on concave parts of twisted roots, but, in such cases, the buds of the laterals were present before the twisting of the mother root had taken place.

In trees grown in the open the development of lateral roots on the convex side can be of practical advantage, since the plant is thus more firmly anchored and extends over a greater area of soil containing food stuffs, where otherwise the root branches might not have penetrated. But where the whole root ball has only a definitely limited soil space at its disposal, as in potted plants, disadvantages arise which must find expression in the production of organic substances. We can perceive these disadvantages at once, if we observe more closely a pot said to be "root bound." The greatest number of young roots have grown out towards the periphery and been so pressed against the porous sides of the flower pot, that many fibres are broken off when the pot is removed. Part of the root fibres have stuck fast like bands or membranes and have died. The latter circumstance is especially apparent in palms and Dracaenae, in which the dead roots consist only of the stele and the outer bark, which has shivelled up like a papery covering.

The straining of the roots toward the side of the pot may be attributed to the need of oxygen. Naturally this demand is less easily satisfied as the network of roots fills the ball of earth more closely. To this must be added the *secretions of the root itself*. Czapek[2] determined that these secretions may be ascertained in moist air as well as in water cultures. In air saturated with vapor they are frequently observed as drops on the root hairs, the result of a strong internal pressure in the cells.

Minimum amounts of potassium, calcium, magnesia, sulfuric, hydrochloric and phosphoric acids are eliminated. Potassium phosphate, causing the well-known reddening of litmus paper, is somewhat more abundant. In regard to acids, Czapek found that the presence of lactic and acetic acids could not be proved, but that,on the contrary, formic acid is found not infrequently in its potassium salt as a diffusion product of the living, youngest

[1] Pollock, James, The mechanism of root curvature. Botan. Gaz. Chicago, XXIX, 1900. pp. 1 ff.

[2] Czapek, Fr. Zur Lehre von den Wurzelausscheidungen. Jahrb. für wiss. Bot. 1896. Vol. 29. Part III.

parts of the roots. Potassium oxalate was eliminated by hyacinth roots. Carbon dioxid, however, must be considered primarily and causes the rock etchings, as it occurs dissolved either in the water of the root-hair cells or of the soil interstices. Monopotassium phosphate and carbon dioxid among the root secretions must be especially considered. In pot cultures the latter is of especial importance. It is retained in the root balls in great quantities, the more thickly matted they are and the wetter they are kept by the grower. The production of carbon dioxid is greatly increased by the respiration of the soil micro-organisms which in their metabolism decompose the carbohydrates and other organic substances. For instance Stocklasa[1] found alcohol, acetic acid and formic acid in forest soil and finally carbon dioxid and hydrogen. The hydrogen often unites with oxygen to form water. Lack of oxygen and the excess of carbon dioxid kill part of the roots and the process is gradually evidenced when plants are grown in small pots, even if over-abundant foodstuffs be given them by fertilizing. However, if fertile earth alone is used, without subsequent additions of fertilizers, the roots, becoming thickly matted on the walls of the pot, do not touch the ball of earth actually as they develop on top of older roots. In such cases, they cannot further draw from the soil the food materials needed in growth.

Early investigations by Hellriegel[2] prove that excessively limited soil space in itself limits production. To perform these experiments many annual and perennial agricultural plants (barley, peas, buckwheat, clover, etc.) were sown in glass containers of different heights in as uniform garden soil as possible and were grown with an observance of all the precautions used in sand and water cultures. In order to prevent any question as to the exactness of the results obtained due to a different amount of soluble nutritive elements control experiments were made with an abundant addition of fertilizers, under otherwise similar conditions. The result was, that no difference in production whatever was shown in favor of the fertilized plants, that those not fertilized must thus have found in the unfertilized garden soil all the nutritive substances that they needed for their production. An indirect proof lay also in the results of the experiments given by the unfertilized plants when compared with one another. The yield showed in fact, that clover in the first year had produced about as much dry material as the other varieties of plants. This did not prevent the clover, however, from producing in the second year on the same soil a second crop and in fact a crop two or three times as great, and even in the third year it produced as much as in the first year. From this it is evident that the amount of nutritive substances could not play a *rôle* in any of the experimental pots, since they were everywhere present in excess.

If now, however, the amount of dry substance increased with the size of the container, this result could be ascribed only to the influence of the

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[1] Stocklasa and Ernest, Ueber den Ursprung, die Menge und die Bedeutung des Kohlendioxyds im Boden. Centralbl. f. Bakteriologie etc. Section II, Vol. XIV. 1905, p. 723.

[2] Hellriegel, Beiträge zu den naturwissenschaftlichen Grundlagen des Ackerbaues. Braunschweig. Vieweg, 1883. pp. 184-224.

volume of the soil. The plants under experiment stood in glass cylinders of the dimensions and contents given below, received steadily from 30 to 60 per cent. of the water required by saturation of the soil and resulted with *clover,* as follows:

Height of the Cylinder.		Diameter in the Clear.
I.	96 to 99 cm.	14 cm.
II.	65 to 67 cm.	14 cm.
III.	34 to 35 cm.	14 cm.
IV.	18.0 cm.	14 cm.

Earth content. Air dry.	Absolutely dry.	Harvested dry substances, in the years 1872, 1873, 1874.
19,500 g.	18,600 g.	417.2 g. with 6.92 per cent. pure ash
13,000 g.	12,400 g.	254.6 g. " 6.97 " " " "
6,500 g.	6,200 g.	173.0 g. " 8.08 " " " "
3,250 g.	3,100 g.	76.8 g. " 8.45 " " " "

Since, in the containers with a very large soil volume, too great a consolidation, therefore somewhat abnormal conditions for some plants, has appeared, because of the sudden addition at first of great amounts of water saturating the soil to 60 per cent. of its water capacity, Hellriegel, in his harvest tables, explained especially the results for the sizes III and IV. From this it appeared that, with *peas,* an amount of soil of

3,100 g. gave on the average, 29.97 in dry substances.
6,200 g. " " " " 47.94 " " "

For *peas,* therefore, the proportion of the soil was 1:2.
" " " " " " " harvest was 1:1.6.
For *beans,* therefore, the proportion of the soil was 1.2.
" " " " " " " harvest was 1:1.8.

In 1872, exactly the same proportions in harvest results were found for barley as for beans. We omit here the repetition of the figures, since those cited show clearly enough that, in two equally wide, but unequally tall vessels, both containing nutritive substances in excess, and steadily receiving the favorable amount of water, the harvest came out as 1:1.6 up to 1.8, if the amounts of soil bore the proportions of 1:2. Thus a strikingly evident influence of the soil volume may be confirmed and the question now is, how this influence may be explained.

Hellriegel found that the ***height of the yield stood in inverse ratio to the amount of the mechanical resistance,*** which opposes the development of the root-network of the plants under experiment.

If commercial growers get apparently opposite results and find that the growth in small pots is great and quick, the explanation lies in the fact that they use a very rich earth and highly concentrated solutions are present in the soil. Comparative measurements showed, however, that the root development in rich nutrient solutions is essentially shorter than in weakly concentrated ones. Hence the demand of the root fibre is actually smaller.

However, in the same length of time, the root makes a stronger growth when kept under glass, or in hot beds, than where the plants are in the open;—for these glass cases all have bottom heat. Finally, the aërial axis finds itself under conditions making possible an especially rapid and abundant development. The atmosphere rich in water vapor and carbon dioxid develops the largest individual cells possible with comparatively little transpiration, hence, the turgid and significant large size of the foliage. Therefore, in garden *cultures* in *small* pots, the root is better and earlier formed and utilized, so that the injuries due to root curvature and bruising make themselves first felt at a time when the aërial axis has already made a considerable growth. That growers, however, clearly recognize the disadvantage of small pots and, when possible, do without them is evident from the so-called *"feeding cultures"* (forcing). In this the specimens are shifted into larger pots as the root branches penetrate to the sides of the pot.

Dwarf-growth (Nanism).

The dwarf conifers found in trade under the name *"Japanese or Chinese Trees of Life"* show an interesting effect of the influence of a limited soil space. The figure on the next page illustrates a living specimen which has been classified by the well-known firm J. C. Schmidt (Berlin) as *Thuja obtusa* and kindly placed at our disposal. The tree, with the pot, is 86 cm. high in all,— and 60 cm. high above the soil. At its greatest width the crown is 80 cm. across. The base of the trunk, divided into several protruding ridges, has a diameter of 19 cm., the trunk at the height of the crown, where the branches appear, one of 12 cm. This healthy specimen, with a dense crown, whose age is estimated to be 100 years, cost $87.50.

In literature, notes may often be found referring to the skill of the Japanese and Chinese in growing dwarf specimens of trees, hundreds of years old for table-decoration[1].

Our examination of the trunk from a dead tree destroys the halo of the miraculous, with which these productions of Japanese and Chinese horticulture have been surrounded. A section 8 cm. long and 6 cm. at its widest diameter showed most excentric annual rings. The distance of the pith from the bark amounted to 1.5 cm. at one side of the trunk and to 6.5 cm. at the other. Counting with a magnifying glass showed 30 annual rings on the wider, but only 15 on the narrower side. On the side favored in growth, a great variation in the breadth of the annual rings was noticeable. Four

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1 In an article on "dwarf growth in the vegetable kingdom,"* Grube quotes a report by Sir Geo. Staunton, from "des Grafen McCartney Gesandtschaftsreise nach China," Berlin 1798. Staunton saw in Ting-hai, spruces, oaks and orange trees none of which were more than 2 feet high and on which fruit had set abundantly. At the base of the trunk the soil was covered with layers of stones weathered and covered with moss giving the pots the appearance of great age. "Throughout China, there is a great liking for these artificial plant dwarfs for we found them, as a rule, in every house of any pretention whatever." It is there further related that the "lilliputian" trees were propagated by binding loam or garden soil around different branches. This was kept moist until the branches developed new roots in the earth ball; they were then cut off. We still use this process in the layering of branches or top shoots and the covering of the cut places with moss. This plan

zones could be distinguished. Each of these ended with very slender rings, the tracheids of which had especially narrow lumina and had become browned through resinosis. Otherwise the wood was healthy. In its dimensions the bark corresponds to the section,—i. e., on the side of the narrower rings, it was 1.5 mm. thick, on the other side 4 mm. On the narrower side, a depression was found, in which a scantier development of the wood had been equalized by a thicker formation of bark,—up to 5 mm. There was shown here a tendency to loosen the individual bark scales between the flat cork layers resembling full cork.

Fig. 15. Dwarf specimen of **Thuja obtusa**, 60 cm. high and 80 cm. wide. (Orig.) At the base of the trunk may be seen the division of the aërial axis into a number of root branches projecting above the pot.

Thus the statements as to the great age of the trees are seen to be erroneous. These cannot be more than some thirty years old and their dwarf growth, in our opinion, can be obtained by keeping the plants in the very

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was followed in China, because it had been observed that an artificially produced dwarf character is hereditary. When the tendency has become hereditary it is strengthened in the new individual by turning down the end bud of the main shoot and bending it with wire in another direction. "If it is desired to give the dwarf tree the appearance of an old, already half dead tree, the trunk is often covered with syrup to attract ants and these, after they have eaten the sweet, immediately injure the bark, giving it thereby a brownish, half-weathered appearance."

Rein** describes the Japanese process which is somewhat different. They call the dwarfing or "Nanisation" "Tsukurimono." This expression is not used in the new book by Ideta***. According to Rein, the dwarf growth is secured by choosing

smallest pots until they are root-bound; then transplanting into a large pot, in which the root crown is raised up above the pot in order that the root ball may have full benefit from the soil. After the year of transplantation, wide annual rings are produced at first, which become narrower as the plant becomes root-bound until the growth has become very slight and the last annual ring formed is made up of a few, browned autumn-wood tracheids. In this way the stilt-like trunk bases, borne on the freely exposed root branches, are produced. The crown is probably kept thick by a light cutting back of the tips of the branches, obtaining thereby a greater ramification. In the same way the root balls might have been pruned at each transplanting. We conclude from the porous places filled with full-cork, which occur scattered in the bark, that the trees have been kept wet. At any rate we would have no difficulty in growing trees in such decorative dwarf forms from the genera Thuja, Thujopsis, Biota, Cupressus and similar ones by limiting the soil content.

A corresponding treatment is recommended here and there for deciduous trees and plants. In forcing woody blossoming plants it is desirable to have for sale small specimens as full of bloom as possible. To attain this end, the bushes are planted in small pots, cut back and kept until spring, as long as possible, in cool dark cellars in order to retard the growth beyond the natural time of awakening. Ice cellars serve best in this connection. When vegetation has advanced considerably out of doors the plants are brought out. They now find a very different combination of vegetative factors for the maturing of their growth. Instead of moist spring air, a comparatively slight warmth of the sun and long, cool nights, the plant finds dry, bright, long days with little precipitation. As a result the branches remain short and the eyes easily develop blossom buds.

It will not be out of place to call attention to the fact, that in keeping the bushes in *warm* cellars, an opposite result is obtained,—namely, absolute unfitness for forcing. The warm, dark place where they are kept produces deformed, very premature shoots, which, when brought at last into the open air, either dry up or gradually and slowly lengthen to whip-like, blossomless wands. The stored-up material has been wasted in the cellar in forming the deformed shoots.

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especially small seeds from under-developed plants. These little trees are pruned and transplanted frequently into as small pots as possible. The cross-section described above in the text shows this. Further, the trunk and branches are twisted and bent toward the horizontal. It is said that the root ball is cooled. Among varieties of plants used especially in Japan for the growth of dwarfs are mentioned the toy varieties of **Acer palmatum**, which are budded, "greffe par approache." Further **Pinus massoniana** and **P. densiflora**, **Podocarpus Nageia**, **Sciadopytis verticillata**. Among fruit trees the Kaki plum. **Diospyros Kaki**, is suitable for this, the Mume-plum, **Prunus Mume** and Sakura, **Prunus Pseudocerasus**, as well as **Amygdalus Persica**. Among decorative plants are mentioned **Evonymous Japonica** and the bamboo.

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* "Zwergbildung im Pflanzenreich" Gartenwelt, 1904, No. 49.

** Rein, J. J., Japan nach Reisen und Studien. Leipzig, Engelmann. Vol. II., p. 315.

*** Ideta Arata, Lehrbuch der Pflanzenkrankheiten in Japan. 3rd Ed. Tokio, Shōkwabō, 1903.

The most frequent occurrence is *dwarfing due to scarcity of water.* Like every other organism, the plant has the ability of adjusting itself within wide limits to different conditions. An individual, accustomed from its youth up, to a very scanty amount of water, can pull through with half the amount of water used by a plant of the same species and variety, which had developed with excessive water. Naturally the structure of the whole individual is adapted to these conditions. More thorough investigations have been made with barley[1], which was cultivated with a varied water content in the soil (10, 40, and 60 per cent. of the soil's capacity for absorbing water). The most favorable water content for growth might be found possibly between 50 and 60 per cent. of saturation.

In the experiment it was shown that the plant even with only 10 per cent. of water had regulated its organization. Little leaf and root substance had absolutely been formed, but the proportion between grain and straw was normal; therefore about as much dry substance in the form of grain as in the form of straw. With the same amount of food in the soil, the dry substance increased as the roots obtained additional water. With too much water, i. e., more than 60 per cent. saturation, very little dry substance was produced absolutely and this small amount was worthless since the proportion between straw and grain was changed,—to the detriment of the latter. Measurement of the leaves showed that the grains grew longer and wider, when water was supplied regularly and more abundantly. These larger leaves, found with a greater water supply, are due partly to the increased number of cells, partly to their greater distention. If the individual cells of the upper epidermis are larger, it may be assumed from the very beginning, that the respiratory apparatus (the stomatal cells) will share in the greater stretching of the upper epidermal cells and will also appear to be the more widely separated thereby. Direct measurement confirmed this assumption, so that therefore for each square centimetre of a leaf grown with abundant water, fewer but larger stomata will be found, than when plants are grown with a scarcity of soil water. H. Möller has determined by experiments[2] that plants dwarfed by lack of water (Nanism) are structurally different from plants whose dwarfishness is due to a scarcity of mineral substances in too weak solutions. In the latter the narrower leaves are probably not due to narrower cells, resulting from water scarcity, but to a smaller number of cells, since measurements show the same cell breadth and the same size of the stomata in plants from a satisfactory nutrient solution and from an insufficiently concentrated one. These differences are easily explained. When the mineral substances are insufficient the cell increase will suffer only from water scarcity. The cells are less distended. As shown by some of Möller's experiments with *Bromus mollis,* this nanism is not hereditary, since specimens of huge size can be grown from the seed

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[1] Sorauer, Einfluss der Wasserzufuhr auf die Ausbildung der Gerstenpflanze. Bot. Zeitung 1873, p. 145.

[2] H. Möller, Beiträge zur Kenntnis der Verzwergung (Nanismus), Landwirtschaftliche Jahrbücher von Thiel. 1883, p. 167.

of dwarf plants. Yet, with equal vegetative conditions, seed from normal plants produces more vigorous specimens than that from dwarfed plants.

The case of nanism due to scarcity of nutritive substances, which Möller studied, is not rare in sandy soils. The lack of nitrogen plays the chief part here. This nanism is usually characterized by the fact that, besides the general reduction, the relations of the separately produced organs have been changed. In proportion to the whole growth, the root undergoes a greater distention; but the sex organs suffer a greater retrogression. The number of blossom eyes is very small. Instead of a cluster or a head, there is often only a single blossom. Where a greater number of blossoms are formed single seeds develop which can germinate. It is easy to understand that the leaf-forms are simplified.

In discussing dwarf growth, the phenomena of *bud variation* must be considered. These have no connection with soil conditions or other external vegetative factors. The form of growth up to this time is so changed by some impulse or stimulus, acting temporarily or persistently, that the organic substance is used up in the form of more numerous, shorter, usually thicker, short-leaved branches instead of fewer slender, large-leaved ones, in this way producing *witches-brooms*. In many cases the incitement to such a changed direction of growth may be found in parasitic attacks. The fungus genus Taphrina (Exoascus) especially irritates the branches of various deciduous trees resulting in the formation of witches-brooms (see Volume II, page 179). In other cases we find rust fungi or mites of the genus Phytoptus. Besides these forms due to parasites, however, some surely exist in which other organisms are not active. We find especially in herbaceous, quickly growing plants (Campanula, Pelargonium) the occurrence of a *bud disease (Polycladia)* as a correlation-phenomenon.

In sickness or loss of blossoming branches, small fleshy bunches are formed, at times, at the base of the stem, made up of closely set bud-eyes, some of which grow out into sickly branches. In diseased thickets growth is often exhausted by a continued new formation of short branches, because the blossoming axes no longer lengthen, but stop growing and turn yellow. In *Calluna vulgaris,* instead of long blossoming branches, we find blossomless bunches of twigs, pyramidal in form, which might also be called witches-brooms.

In other cases polycladia and bushy forms are produced by the development of normally formed but still dormant lateral eyes, when the buds of the tips have been injured. This takes place when wild growths choke out cultivated ones. In conifers, the heart buds grow out and form bushy crowns, which are called *"rosette-growths."* The so-called *"cow-bushes"*—due to injury to beeches, alders, etc., from the grazing of cattle, are similarly explained.

Pure bud variations are numerous. In them the growth in length of the individual branches is restricted without any recognizable cause, resulting in a greater and more rapid development of lateral branches. Among

the actual forms of witches-broom, the tendency at present is to place under this head of bud variation the numerous spherical bushes of the spruce witches-broom[1]. The greatest number of examples is furnished by the many cultivated plants of our gardens in the so-called globe forms of conifers and in the dwarf forms of blossoming bushes. In the short-lived summer plants (Ageratum, Zinnia, Tagetes, etc.) we find that the dwarf growth can become an hereditary peculiarity, persistent in the seed.

Too Thick Seeding.

A limitation of the soil space and a struggle for water and nutritive substances is always produced by too thick seeding. The struggle of the plants with one another for their food appears earliest and sharpest in sandy soils. Besides the dwarfing of individual specimens, *the weakening of reproduction* deserves especial consideration. This becomes evident not only in the decrease of the blossoms, but also in the change in their character and becomes especially perceptible in horticulture, because staminate blossoms are produced predominantly. The unavoidable scarcity of nitrogen is also a factor. The greater the amount of nitrogen supplied, the more abundant the meristem, rich in cytoplasm.

Hoffmann[2] gives the results of many cultural experiments in pots and open ground, to determine the influence of too thick seeding for different plants. In this, for every 100 pistillate blossoms there developed the following number of staminate ones:—

In	With Too Thick Seeding.	With a more scattered position of the plants.
Lychnis diurna	233	125
" "	200	77
" *vespertina*	150	73
Mercurialis annua	100	90
Rumex Acetosella	152	81
Spinacia oleracea (average of several sowings)	283	76

In Cannabis his results were contradictory, which may be explained by a consideration of Fisch's statement[3] that the proportion of the sexes in hemp is already determined in the seed,—that, therefore, external influences can bring about no further changes. Belhomme maintains that the form of the hemp seeds admits of conclusions as to the sex of the future plant, since the longer or the more spherical form, as in bird's eggs, indicates a staminate or a pistillate individual.

Since the phenomena appearing with too thick seeding may be traced essentially to scarcity of food substances, further examples will be cited when the scarcity of nitrogen is discussed.

[1] Tubeuf and Schröter, Naturwissensch. Zeitschr. f. Land- u Forstwirtschaft. 1905, p. 254.
[2] Hoffmann, H., Ueber Sexualität. Bot. Zeitung. 1885, No. 16.
[3] Fisch, Ber. der Deutsch. Bot. Gesellsch. 1887. Vol. 5. Part 3.

2. UNSUITABLE SOIL STRUCTURE.

a. Light Soils.

Disadvantages of Sandy Soils.

The way in which the individual soil particles are related to one another, is termed the structural condition. If the constituents of the soil are simply laid one above the other in separate grains we speak of a *separate granular structure*. In soils under cultivation, however, the individual soil particles are found united into different kinds of aggregates, called a *friable structure*. While, in the first case, each soil grain has a homogenous constitution, the soil grains in the second case are porous and not homogenous, therefore can be more easily transformed. The content in soluble salts, the activity of the animal world in the soil and the action of plant roots and their secretions, as well as the physical processes of working the soil, determine the formation of a friable structure. The amount of space between the individual grains will vary according to their size and arrangement. Ramann calculates the porosity volume of equally large soil particles, according to whether the particles are arranged regularly in rows on top of one another or between one another, as fluctuating between 47.64 per cent. (greatest porosity) and 25.95 per cent. of the whole volume (closest stratification)[1].

While in the friable structure, because of the different individual particles, a continuous change in size and arrangement takes place, due to mechanical and chemical influences, in the separate granules, most distinct in stony and gravelly soils, the physical relation is more regular and therefore more significant.

We have already spoken of the influence of actual sandy soils and the changes which roots can experience when growing in cracks in rocks. The injuries to vegetation, which are caused by too loose a structure of stony soil at the disposal of the root, seem lessened when the blocks of stone are weathered to rubble. Fine, earthy particles are produced, especially when the stones are easily decomposed (many granites, Gneiss, Syenite, etc.) affording the roots more abundant food and firmer support. Next to the great possibility of being rapidly heated through, the factor acting most injuriously is great dryness, which prevents a decomposition of organic substances leading to the formation of humus; this, under certain circumstances, forms moors. Forestry in mountains must take such conditions into account. *Sandy soils* come under consideration for field cultures on the level. As soon as these possess greater admixtures of clayey substances (loamy sand) or of humus, they form most productive soils and therefore find in this discussion no further consideration. Sandy soil is unfavorable for cultivation only when the sand is truly quartz sand and is either pure or is present in a very high per cent. (70 to 90 per cent.)

[1] Ramann, Bodenkunde, 2nd. Ed., p. 222. Berlin, J. Springer, 1905.

In such cases, the slight absorptive capacity should be mentioned first of all as a hinderance to cultivation. The diseases caused by scarcity of water and food substances are pre-eminently peculiar to sandy soil. The more clayey and humus admixtures present, the more the danger disappears, in so far as it is not brought about again in another way by the washing away of considerable amounts of easily soluble mineral substances.

Such an erosion takes place much the more quickly when the decomposition of organic substances, which occurs easily under the influence of warming and aëration, is increased by other conditions. On this account one must be especially careful in removing *forests* and *litter*. In deep, sandy soils, the removal of the litter holding its moisture is disadvantageous since the organic substances present are but very little decomposed by atmospheric influences and bacteria, and accumulate as *raw-humus*, which can finally give rise to the formation of meadow ore. According to Ramann, in lower positions the deposition of raw-humus gradually leads to complete marshiness, as in the large moors of North Germany, which almost without exception have originated from land which at one time was covered by forests. The humus is beneficial only when mixed with sand, since the friability of the soil and its water content is increased and its capacity for heating reduced.

This capacity for heating and giving off heat of sandy soils is an essentially harmful quality. Pure sand possesses the greatest capacity for giving off heat and consequently the greatest capacity for *becoming wet with dew*. The process of taking up and giving off heat decreases as the sand is finer grained and whiter. Sand of the latter kind, for example, is that rich in calcium, while, of colored sands, the ones rich in iron hydroxid are very warm and cool off slowly, behaving therefore like sand mixed with some clay.

Associated with the great fluctuations in temperature peculiar to sand is the poor capacity for conducting warmth. As a result of difficult equalization its subsoil has a more even temperature, since it is warmer in winter and cooler in summer than under more binding soil coverings. The *danger from frost* is increasedly greater and more injurious. The rapid warming in spring days forces vegetation prematurely and the great drop in temperature at night is injurious, while the plant would be uninjured if it started later in a soil containing water and rich in clay.

The sandy soils of fine constitution and slight coherence present the greatest possibilities for injury to crops. The injurious effects of drifting sand are shown in the *sand dunes*. Even if the dunes reduce the severity of the sharp sea winds for plants near the coasts, they are nevertheless injurious since they advance further and further inland, covering all plants. The inability of the land breeze to blow back during the night the sand which the sea breeze has swept over the land by day is due to the fact that the land breeze is heavily laden with dew and tends to compact the sand again. If the danger of being covered with sand threatens and artificial protection is

The production of carbon dioxid forms a measure of the energy produced by a root in raising water, boring into the soil and other life-functions. Kossowitsch has furnished quantitative determinations on this point[1]. He found that mustard plants in water cultures assimilated about three times as much carbon for the life processes of their roots, as was necessary for the formation of the roots themselves.

The strength of the root activity, especially in lifting water, might depend also on the differences in temperature between the atmosphere and the soil. The greater this difference, the more energetic the work done. MacDougal's[2] experiments in the New York Botanical Gardens prove how great such differences may be. He found in June, that the soil temperature at a depth of 30 cm. was at times 20°C. lower than that of the air. Naturally the water content of the soil here becomes a decisive factor and the differences decrease as the soil becomes drier and more accessible to the air. The moisture holding capacity and, in sandy soils, the amount of production will depend, in the same soil, on its granular structure and will be the greater as the sand is finer grained. Livingston and Jensen[3] experimented on this subject. They cultivated different plant species under similar conditions, in soils which contained admixtures of different sized quartz grains in the different experimental series. It was shown that the best growth always occurred where the quartz sand was very fine.

By means of the above observations we get an insight into the disturbances which must take place, in the activity of the roots, if the water supply of a region is less, because the ground water level has been lowered. An old tract of trees survives, because part of the deep growing roots reach the ground water level and are able to compensate the loss by evaporation of the tree crowns, when the soil water is reduced to a minimum during periods of extended dryness. The roots lying in the earth, permeated by the ground water, are adapted to these conditions. When these roots are permanently exposed to drought they are destroyed or function feebly. Not only the economy of the tree suffers from the insufficient water and food supply, but even the soil itself, since, entirely aside from the paralysis of bacterial activity, the secreting ability of root hairs and tips affecting the decomposition of the soil also ceases. The soil becomes *"lean"* and the trees begin to show dead branches in the periphery of their crowns. Since parasites settle on dying parts completing the destruction of the tissues, this blight of the tree tops is explained in the majority of cases as a purely parasitic disease and treated as such.

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1 Kossowitsch, P., Die quantitative Bestimmung der Kohlensäure, die von Pflanzenwurzeln während ihrer Entwicklung ausgeschieden wird. (Russ. Journal f. experim. Landwirtschaft, 1904, Vol. V, cit. Centralbl. f. Agrikulturchemie, 1905, Part 6, p. 367).

2 MacDougal, D., Soil Temperatures and Vegetation. Repr. Monthly Weather Review for August 1903, cit. Just, Bot. Jahresb 1903, II, p. 557.

3 Livingston, B., and Jensen, G., An Experiment on the Relation of Soil Physics to Plant Growth. Bot. Gaz. Vol. XXXVIII, cit. Bot. Centralbl. 1904, No. 50, p. 617.

The Dying of Alders.

Alders are most sensitive to a lowering of the ground water level and it is easy to find diseased tracts of alders near newly cut canals or regulated river beds. In the works of the *Royal Biological Institution for Agriculture and Forestry* at Dahlem, near Berlin (1905), Appel[1] has published a study of the death of alders well worth consideration. He found on the dying branches a species of the genus Valsa known to attack diseased or dead branches,—namely, *Valsa oxystoma*—and stated that the fungus is parasitic only when the alders become susceptible, owing to abnormal circumstances. Drought is the chief determinative factor. Other disturbances in nutrition (injury to the roots, girdling, etc.) can also create a predisposition to fungus attacks but, if the alders are enabled to make a healthy growth, the disease disappears. When alders are found dying on apparently moist, impermeable, ferruginous soils, drought may be considered to be the cause. On such soils, the alder spreads it roots only very superficially and in continued dry weather there is a very marked scarcity of water in the upper soil layers, which at once makes the alder foliage wither and dry. The beautiful tracts of trees in the Tiergarten in Berlin, especially the oaks, unfortunately show similar results from surface drought, and to an ever increasing degree.

Naturally canal and river bed regulations do not always necessarily cause the lowering of the ground water level. In the old Botanical Garden in Berlin, for example, the building of the subway dried up the water in the ponds and as a further result the tree crowns rapidly became blighted. In other instances we found that the spread of brick-paving and clay-diggings near forest tracts accelerated the death of the alders because the deep clay pits had withdrawn water from the forests.

The dangerous effects of lowering the ground water level often fail to impress us sufficiently, since, in some tracts of woodland, the same tree species (suffering from blight of the crowns in soils from which the water has been removed) thrive in very dry places. Under such circumstances the fact that the lack of water in itself does not cause the death of the trees, but the ***abrupt transition*** from a previously well-watered condition to great drought in the deeper layers of soil is overlooked. We may plant all our trees in very dry soils and the individuals will adapt themselves to the existing vegetative factors and the leaves will become small and coarse, the internodes short. But a sudden great change in this condition will have most serious results. If, however, such changes are unavoidable, our theory gives only one line of action to preserve the plantation,—namely, ***to plant young trees between the old ones.*** These will adapt themselves to the changed vegetative conditions.

Street Planting.

The preservation of trees along the streets and small parks is of the greatest importance for the hygiene of cities. The greatest injury results

[1] Vorläufige Mitteilung in d. Naturwiss. Zeitschr. f. Land- u. Forstwirtschaft. 2 Jahrg. 1904.

from the present methods of street paving which fill the spaces between the stones with a binding material, and even at times the asphalt covers the soil entirely. The injury to the trees is two-fold; on the one hand, the air is cut off, on the other hand watering is insufficient. This affects the older trees principally. For young trees, the circle of sod around the tree is sufficient, especially if an iron grating laid over it prevents passers-by from tramping the soil. We find that old trees die much more quickly when a regulation of sidewalks and a lowering of the ground water level is combined with street paving. In large cities another factor must be added, i. e., laying pipes for gas, electricity and sewers. In all this work, the chopping off of the larger root branches is unavoidable.

Therefore, the root space is not only limited by the pipes, and the soil dried, but also the trees' organs for the absorption of water are decreased. To this cause may be ascribed the gradual break up of old trees as shown by the dying branch tips.

Different varieties of trees suffer in varying degrees and the linden, a favorite and most frequently planted species, is among the most sensitive of varieties. In it the dryness of the soil, with which is associated also dryness of the air, is expressed by a premature defoliation. The large leaved linden suffers more quickly than does the smaller leaved variety, and it is a well known phenomenon, that, in the summer months, when the inhabitants of the city want shade most, the linden and chestnuts often for some time have leaves only on the outermost tips of the branches. The older leaves, covered with red spider, have dried up and fallen. The city adminstration endeavors to overcome this condition by abundantly watering the ground about the tree thereby favoring a second leafing out in the late summer, which is produced even without artificial watering when the trees have lost their leaves prematurely. In this buds are forced to unfold which should develop in the following year; under such conditions a second time of blossoming is also often produced (Aesculus, Robinia).

Many of the shoots artificially produced by this watering do not mature sufficiently and are injured by frost. Thus in different years, in the middle of the favorable early summer, the twigs die off accompanied by fungous infection. The winter, therefore, did not kill these less mature twigs, but made them susceptible to fungous attack, thus giving the primary cause for later death. This theory also explains the death of the cherry trees along the Rhine, which has occupied the attention of investigators during the last few years[1]. A Valsa *(V. leucostoma)* plays a part here as in the case of the alders. We will return to this case in the chapter on injuries due to frost.

Such bad conditions in street planting may be avoided by a choice of less sensitive varieties. First of all, the elm should be recommended as such; this has the added advantage of being very resistent to the acid gases of smoke. Also oaks and plane trees are used with advantage according to the kind of soil present. In broad, airy streets *Acer platanoides* also

[1] Cf. Deutsche Landwirtschaftl. Presse 1899, Nos. 83, 86, and 1900, No. 18.

thrives well, but suffers often from honey dew. The Robiniæ, especially the so-called ball acacia, retain their foliage well even in great drought, but offer only a little shade and put out their leaves late, usually losing them early in autumn. Therefore, when Robinia is planted, arrangements for watering should be made, in which drain pipes perhaps ½ metre below the pavement are put at the distance from the trunk where the newer roots lie. These pipes can be filled when necessary from hydrants. However, attention should be called to the fact that watering through drain pipes can be used only in the hot summer months, because otherwise there would be an excess of water in the soil with much more disasterous results than those due to a scarcity of water. Finally, we think that a sprinkling of the tree crown at night should be recommended especially where watering may be carried out only through the ground about the tree.

We must emphatically state that watering by means of water drains can be recommended only for light soils with a permeable subsoil. By constantly watering heavy soils with a large water content, the soil will become baked and compacted, resulting in a scarcity of oxygen and an excess of carbon dioxid as elsewhere described, which combination will bring about the decomposition of the roots. Mangin's[1] studies will be cited here as a single warning example. He worked especially on the meagre growth of trees in city planting and found the soils choked to such an extent that the carbon dioxid content of the soil air increased from 1 to 5 and 8 per cent. and even to 24 per cent., while the oxygen content fell to 15, 10, 6 and even 0 per cent. As a matter of course all the trees with such an environment will die. (Compare "Too deep planting of trees," p. 98.)

Effect of Drought on Field Products.

The results of continued scarcity of water, felt most quickly in sandy soils during great heat, are determined naturally by the time the dry period begins. If it sets in in May, as in 1904, i. e., when growth is most rapid and the activity which should furnish the material for maturing of fruit is reduced, the effect is most serious.

In grain, sowing of summer seed suffers most under our cultural conditions, when planted at the usual time. This is easily understood when we consider that winter seeds sown in the autumn can, during the whole autumn and the early spring, fully develop their roots and obtain a sufficient formation of shoots. They thus utilize the undisturbed activity of their lower leaves. In this way the winter seed meets the dry period in a strong and well-prepared condition, while summer seed, even where it sprouts normally, enters upon the hot, dry period at a much younger developmental stage. Accordingly the leaves ripen prematurely, their period of work is therefore more limited and even if the plants develop blossoms and the ovaries, comparatively little organic matter is present for filling out the

[1] Mangin, L., Vegetation und Durchlüftung des Bodens. Annal scienc. agronom. 2 sér. 1896; cit. Centralbl. f. Agrikulturchemie, 1898, p. 638.

grain. The endosperm is only scantily filled with starch; the grains slender and light.

A second injurious effect is the shortness of the straw. This appears especially in summer oats, which on light soils have red stalks and grow scarcely a foot high, maturing only a few small heads instead of the full ones. Barley shows less injury, wheat comes next and finally rye, the most resistent. If the dry period makes itself felt as early as seeding time, the plants come up late and unequally. This leads to a double growth, i. e., to a very irregular maturing of the grain. At the time of harvest many green blades are found among the ripened ones. The former come from the seeds which were left on top at the time of sowing, and which at first did not start, while those more deeply placed found moisture enough for a speedy germination.

In this, limited local conditions often become effective. Thus, for example, one early crop may have drawn more water from the soil than another, or a *potassium fertilizer* is irregularly distributed and keeps the soil more moist in the spots where it has accumulated. The whole development of the plant is also changed by this. I found under otherwise equal conditions that the root shortened when the concentration of the nutrient solution increased and the plant's need for water became less. This is of great significance in soils imperilled by drought.

In the cultivation of sugar beets and all vegetables, grown as seedlings in small spaces and then planted out in the field, the dryness of the soil makes itself felt most of all by preventing the growth of the seedlings since no new roots can be formed in dry soil. Next under consideration is the drying of the foliage, which stops the development of the beets. Experience teaches[1] that, as with grain, *well fertilized fields* survive drought better. Varieties also show differences in this regard. It has been observed that varieties of sugar beets with outspread leaves wilt more easily than do those with erect petioles.

The influence of long continued drought on potatoes shows more in its effect on the maturing of the tubers than upon their setting. The tubers remain small and ripen prematurely. As a rule, this *premature ripening* of early potatoes is of less consequence economically because they are adapted by nature to a shorter vegetative period and because, in the second place, they are rapidly consumed. Only the premature ripening of the later varieties is disasterous, because the tuber has a small content of starch and its keeping quality is much impaired.

Leguminoseae suffer greatly from continued drought when they are grown for fodder. Clover and alfalfa burn out in spots or the second crop fails. The most frequent results with fruit trees are the premature ripening and poor keeping quality of the fruit and premature defoliation.

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[1] Jahresberichte d. Sonderausschusses für Pflanzenschutz. Deutsche Landw. Ges. 1904.

Among the special forms of injury which can set in during long continued, intensive drought, especially in light soils, one especially deserving more thorough discussion is

The Effect of Drought Upon Germination.

When the water scarcity occurs after the seed has passed the first stages of germination, the results are less serious, if dry seed has been sown on open ground than if seed previously soaked has been used. These disadvantages affect the development of the young individual in varying degrees dependent upon the kind of seed and the age of the seedlings when the drought takes place. According to Will's repeated experiments[1] with seeds of monocotyledons and dicotyledons, the seeds of the former seem in general to be somewhat more resistent. The cereals without glumes (wheat and rye) are very little sensitive to a period of drought, if it occurs during germination. Barley and oats, however, are injured more easily, and the horse-tooth maize has very little power of resistance. Saussure[2] found that maize, beans, poppies and garden campion are very susceptible to drought during germination. Nowoczek[3] in his experiments repeatedly interrupted the supply of water, until the power of germination of the seeds was quite lost, and found that the seeds of grains resist the changing conditions of moisture and drought better than rape, flax, clover and peas, which lose their germinating power earlier, but even after a period of drought these seeds can be revived. Experiments on the Gramineae showed that after each drought period the fibrous roots, already formed, died, and the outermost leaves dried up, but that, when water was again supplied, new adventitious roots were formed from the first node (see Vol. I, p. 102) and the last leaves developed further. This statement applies especially to oats and to a greater or less extent to barley, wheat and maize.

It should be considered as universally well-established that soaked and then *carefully* dried seeds, when put again into water take it up more quickly than do air dry, non-soaked seeds of the same size. Such seeds in fact germinate a few days earlier.

Tautphöus[4] and Ehrhardt[5] made experiments giving results which were expected at the start,—viz., that plants suffer so much the more, the further germination has advanced; i. e., the more developed the plumule is when the drought begins, the greater the damage. Will found the seed of peas in part especially sensitive to drying out. The testa was broken by many small cracks in most cases reaching into the inner layers. With repeated soaking, the palisade layer was broken into unequal pieces, the

[1] Will, Ueber den Einfluss des Einquellens und Wiederaustrocknens auf die Entwicklungsfähigkeit der Samen, sowie über den Gebrauchswert "ausgewachsener" Samen als Saatgut. Landwirtsch. Versuchsstationen XXVIII, Parts I and 2 (1882).

[2] Annales des sciences nat. Bot. 1827. Janv.

[3] Ueber die Widerstandsfähigkeit junger Keimlinge. Wissensch. prakt. Untersuchungen etc. von F. Haberlandt, Vol. I, p. 122; cit. Biedermann's Centralbl. I, p. 344. 1876.

[4] Freiherr von Tautphöus. Die Keimung der Samen bei verschiedener Beschaffenheit derselben. München 1876; cit. Bot. Jahresber. 1876, p. 882.

[5] Deutsche landw. Presse, Jahrg. VIII, No. 76; cit. von Will.

testa became slimy and shortly decomposition set in, affecting the cotyledons, which hindered the development of the seedlings. The production of these cracks is due to the increase in volume of the seeds, when soaked, to more than 100 per cent.[1] This produces a pressure on the testa and distends it, making it porous. This porosity can lead with drying even to rupturing. Through these cracks in the testa, the embryo, when moistened a second time, gets much more oxygen for the food-reserve already beginning to decompose, and also large quantities of water are more quickly absorbed. Further, the dissolved organic materials are transferred more easily osmotically. These may act unfavorably on further development. A testa slowly and equally distended, remaining uninjured, will therefore probably more completely utilize the reserve substances of the cotyledons and perhaps indeed force the fluids into the tissue of the cotyledons and the dissolved reserves into the embryo by the turgidity produced by soaking. We cannot enter here more closely into the enzymes occurring in germination and their action, but refer in this connection to the works of Newcombe[2] and Grüss[3].

From these experimental results it can be safely asserted that the use of seeds, which have been soaked until germination has started and then dried off, should be avoided. I am also of the opinion that soaked seed is to be used sparingly every time especially in dry regions. In the first place, in dry regions, the conditions already brought about artificially by drying soaked seeds can be repeated most easily in nature by continued heat and drought and act much more injuriously than if the seed, in such a condition, lay ungerminated in the soil. In the second place the plants become accustomed from the beginning to an excessive water supply. The tissue becomes more porous, richer in water and, requiring more moisture, dries up much earlier with the occurrence of great periods of drought than if the plants had developed with a scanty supply of water. The evaporation in the former condition is greater than in the latter. On this account, growers often follow the rule that for vegetable plants developing rapidly (cucumbers, beans and cabbages) watering must not be discontinued, if the plants have had abundant water when young. I have often found that plants from soaked seeds are less thrifty than plants grown from the same seed which had not been soaked, but which depended upon the natural moisture of the soil.

Treatment of Tree Seeds.

If the germination of tree seeds is interrupted by drought, the results are very disasterous. This is felt most in planting trees whose seeds retain their germinative power only a short time. Nobbe[4] found that the seeds of

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1 Nobbe, Handbuch, p. 122

2 Newcombe, F. C., Cellulose-Enzymes. Annals of Botany 1899, No. 49; cit. Bot. Jahresb. 1899, II, p. 179.

3 Grüss, J., Beiträge zur Enzymologie. Berlin 1899. Festschr. f. Schwendener. Ueber Zucker- und Stärkebildung in Gerste und Malz, III u. IV. Wochenschr. f. Brauerei 1897, 1898.

4 Döbner-Nobbe, Botanik f. Forstmänner. 4th. Ed., 1882, p. 382.

willows lose their power of germination in 5 to 6 days after they have been blown from the parent tree. The seeds of poplars and elms are also proved to be very short lived. Acorns and beech nuts, as a rule, are capable of germination only until the following spring. On an average, ash, maple and fir come under the same head. On the other hand, a large percentage of spruce and pine seeds germinate after 3 to 5 years; however, the seedlings are apt to be less vigorous. The maturing of the seed and the care of it after it has been gathered are important factors. For example, Nobbe found that seeds of *Pinus silvestris,* which had stood in closed glasses in a living room, germinated after 5 years to about 30 per cent. and after 7 years, to 12 per cent. In fact, even after 10 to 11 years, individual seeds were still found capable of germinating. Under the same conditions, seed of *Trifolium pratense,* after 12 years, germinated to 10 per cent., *Pisum sativum,* 47 per cent. after 10 years and in one experiment, *Spergula arvensis* 25 per cent., another year 67 per cent. It is stated that cedars and Italian pines (Piñon) have germinated after 30 years[1]. It is advisable to sow fine seeded conifers soon after ripening. The time of planting, whether summer, autumn or spring, is a question of practical importance. The summer is the most difficult season because the moisture fluctuates to a great extent in the soil; therefore, with trees whose seed must be sowed immediately, as willows and poplars, propagation by cuttings will obviate this difficulty. Autumn sowing is much better and necessary with oaks, chestnuts, hazel nuts, etc. It is recommended for very hard shelled seeds like those of Crataegus, Prunus, Ilex, Sorbus, Rosa, Cornus, Berberis, Ribes, Carpinus, Staphylea, Clematis, etc. The last named kinds often do not germinate for 2 to 3 years, especially in sandy soils. Spring sowing is best because the danger of winter and all injuries due to animals are eliminated. In order not to lose the time between the autumn and spring, the seeds are placed in layers between sand, which is kept damp. This process is called *stratification.*

The importation of seeds of prized decorative trees from their native countries has become a large business. It is important to know the loss of germinating power during transportation. Count von Schwerin[2] in the German Dendrological Society has called attention to the fact that maple varieties cannot withstand any long transportation, so that, for years, not one of the maple seeds brought from the Himalayas had germinated. Also, the seed bed should not be broken up too soon, since many seeds retain their vitality for a long time in the soil. Thus, for example, *Chamaecyparis Lawsoniana* often lies 4 years in the soil, especially in dry years. For years, in the trade in *Magnolia hypoleuca* from Japan, either no seeds germinated or so few that the costs of transportation were not paid. The seeds dried during the journey. Very encouraging results have been obtained recently by leaving these seeds in their fruit and packing them in powdered charcoal.

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[1] and [2] Ueber das Keimen von Gehölzsamen. Der Handelsgärtner 1905, No. 14.

To the statement made heretofore that the seed of Acer retains its germinating power until the following spring, the qualifying statement must be added, that maple seeds of the Campestre group (*Acer obtusatum, A. italum,* etc.), as a rule, germinate only in the second year. Only occasional seedlings may be found after the first year. In many botanical gardens, however, trees of the Campestre series are said to furnish seeds usually germinating early. The explanation of this is that in seeding in such places, the first seedlings are used for propagation. From this it may be concluded that the peculiarity of producing seeds, which germinate promptly, may be made constant by selection. This point of growing the earliest germinated seedlings separately as seed bearers, when making large seedlings, might be recommended for the consideration of plant breeders.

Blasting in Grains and Legumes.

Under these circumstances the seeds do not mature since the plants do not have enough water. Such a condition of great drought is most often found on soils of a very porous structure where evaporation is very great and the capillary movement of water from the subsoil is slight.

Yet great scarcity of water will not always produce a blasting of the blossoms. This depends essentially, as Hellriegel's experiments with grains show, on the development of the plant when the water scarcity makes itself felt. If, following the experiments[1], a grain plant has had only a scanty amount of water at its disposal, beginning at the time of its germination, it reaches maturity in a period of the same length, or perhaps somewhat longer, yet the whole growth is weak. The proportion of the harvested grains to the dry substance, however, is always normal; i.e., approximately half of the dry substance is harvested in the form of grain. As in all vegetative conditions, there is here also a minimum; if the water supply is kept below this, no product worth naming takes place.

If great scarcity of water occurs immediately after germination begins, the grains remain alive for a long time (in the experiment up to six weeks) and later develop vigorously, when the water is supplied in abundance. A period of drought appears to be still less injurious if the grains are still in the milk stage, i. e., have reached their normal size, but have not finished their inner development and become hard. The work of the plant, which now forms no new dry substance, consists in transposing the substances produced in the leaves to the storage organs, the seeds.

In all periods of growth between sowing and ripening, a longer scarcity of water acts more injuriously the younger the plant is at the beginning of the drought. When the long drought sets in while the seeds are sprouting vigorously, the setback resulting therefrom cannot be overcome. The results of continued drought are the more severe, the more water the plant has had in its youth. If a plant has grown luxuriantly with abundant soil, up to the

[1] Hellriegel, Beiträge zu den naturwissenschaftl. Grundlagen des Ackerbaues. Braunschweig. Vieweg 1883, pp. 589 to 620.

setting of the bloom, and then receives a check from a long drought, the grain is not set; a greater or less extensive failure of the harvest takes place, which we may call the blasting of the grain. Ritzema Bos'[1] experiments with "Maartegerst," or winter barley sown in March, are very interesting. A sowing was made on a field where autumn sown winter barley was frozen out. Only a few of the autumn sown plants came through the winter and produced stalks during the summer so that the same field produced autumn and March sown barley. The plants from the March seeding suffered during the hot summer from blasting, while the plants of the autumn sowing, scattered among them, bore a full harvest of grain. With us, besides grain, peas suffer most. Naturally in other plants as well, a failure of the seed harvest can take place, due to the blasting of the blossoming parts.

THREAD FORMATION IN THE POTATO (FILOSITAS).

In this disease ("mules"—of the French) the eyes are deformed; from them grow slender, *thread-like* stems as thick as medium sized yarn. Not infrequently the eyes of tubers comparatively rich in starch did not sprout at all, or if they did, the sprouts were weak; they are unable to break through even a shallow soil covering. The tubers decay usually with the appearance of dry rot, yet the disease has occurred extensively only where the soils, being easily heated, have to withstand long droughts.

Fig. 16 shows the basal part of a cutting grown in a water culture from a potato affected by Filositas; the proportions of the stem, leaves and tuber correspond to the natural size and it is seen that the stems actually are only as thick as a strong thread of yarn. The stolons (*st.*) are also more delicate and have formed tubercles (*k*), some of which have lengthened at the tip and grown out to green sprouts (*b*) or developed scale-like green leaflets (*d*).

The cutting here reproduced came from an experimental culture, the results of which are given in precise figures in the second edition of this manual and lead to the conclusion that in the thread disease of the potato we have before us *conditions of premature ripening which had become hereditary*. Reports from the localities where the disease has occurred, especially from the Marchfeld near Vienna[2], of the cultural methods followed there, substantiate this theory. The potatoes, which were of the earliest varieties, were forced artificially and planted as soon after as possible. Sandy soils on the Marchfeld near Vienna, lime soil near Poitiers[3], had a small water capacity and heated rapidly, consequently with the increasing summer temperature and the superficial position in the upper soil layers the growth of the aërial axes stopped at once. Tubers are formed about this time, but they do not mature, they are filled with starch so that they can be marketed very early and command high prices.

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[1] Zeitschr. f. Pflanzenkrankh, 1894. p. 94.

[2] Altvatter, Das Marchfeld und seine Bewässerung. Oesterr. landw. Wochenbl. 1875. No. 51.

[3] Journal d'Agriculture pratique; cit. Biedermann's Centralbl. f. Agrikulturchemie, 1873, No. 10 und Annalen d. Landwirtsch., 1873, Wochenbl., No. 16.

When young tubers are checked, ripen prematurely and are harvested, the eyes have not developed normally. Shoots developing from these eyes must naturally be weak. If such tubers are used the following year as seed

Fig. 16. The basal portion of a cutting grown in water from a potato tuber with the filament disease (natural size). (Orig.)

for similar cultivation, these phenomena of weakness must gradually increase and result finally in the growth of thread-like stems only. Accordingly the disease is the result of a continued unwise cultural method; viz., an

admissible shortening of the *vegetative* period of growth. To overcome this difficulty the seed must be changed since the method of cultivation will not permit the return to normal seeding.

Diaphysis (Growing Out) of the Potato.

In summers with little rainfall, as, for example, in 1904, one of the most frequent complaints was that the potatoes remained small or when approximately normal size, showed an uncommonly large formation of secondary tubers *("Kindelbildung")*. In Fig. 17 is illustrated one of the most bizarre forms, which shows two kinds of diaphysis (growing out), viz., the actual *"formation of secondary tubers"* and *"water ends."* The stem end of the tuber (at the left side in the drawing) shows two daughter tubers

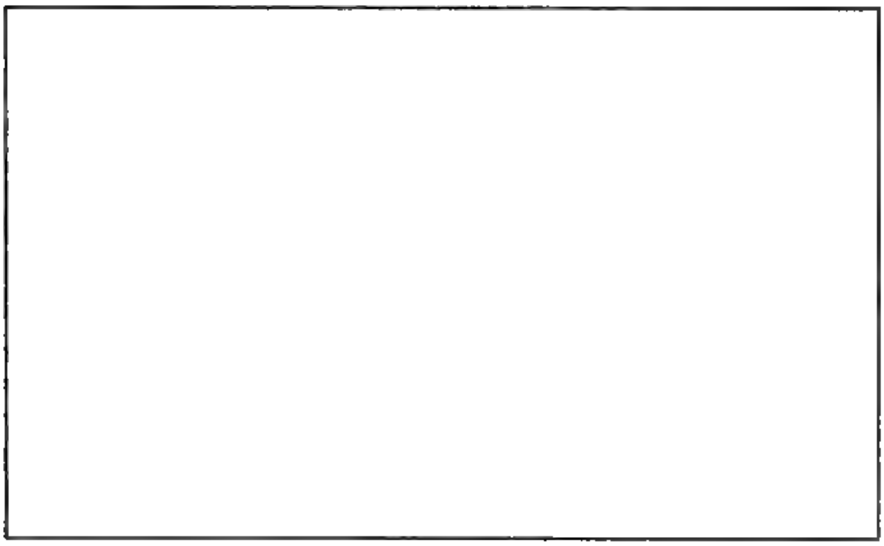

Fig. 17. Prolificated potato; at the left the beginning of complete lateral tubers; at the right, subsequent elongation of the tip end (water ends). (Orig.)

growing on either side at about the same relative position like the arms of an armchair. Toward the tip we find the daughter tubers becoming smaller and smaller, until near the conical end of the tuber (right side of the picture) they are recognizable only as small hemispherical processes.

This malformation is caused by *Prolepsis*, i. e., a premature or hurried development of the eyes. The explanation of this phenomenon is easily found. After prolonged foliage development the underground eyes of the potato plant develop tubers which store the already manufactured starch. The drier the summer, the more quickly the tuber ripens, since, with the regular enlargement and increase of its cells, the starch grains enlarge and the cell walls thicken. The cells (except the youngest about the eyes) gradually lose the ability to increase in size to any extent.

If now, after prolonged drought and advanced ripening, a considerable amount of water is forced up into the tuber, this abundant absorption of

water increases the cell pressure, especially in the young eye cells with their still elastic walls, so that the eye begins to grow. Young shoots sprout from these eyes ultimately reaching the upper surface of the soil. This more unusual condition occurs only after continued wet weather. As a rule, only passing periods of rain force the water into the tubers, an effect lasting but a short time; then the sprout remains short and thickens to the secondary tuber (Kindel).

The cork layer (the skin, smooth in young tubers) shows very clearly how the cells of the ripening tubers lose their elasticity. When the tubers are very ripe the skin becomes rough in most varieties of potato, especially red ones. At first the cells of the cork layer are closely connected with one another but, with the increasing pressure of the swelling parenchyma, the cells are forced apart, tearing the skin. Under these tears new cork cells are formed. This splitting of the skin is greater or less with different varieties. The more split a tuber of an otherwise smooth-skinned variety is, the riper it is and the richer in starch.

Diaphysis of the tubers in many cases has a bad influence in that the quantity of starch which may be regarded as influenced by the soil, is deposited in a less available form than in normal development. Together with the large tubers a great many small ones are formed, which are less mature and therefore poorer in starch. According to the investigations of Kühn[1] and Weidner[2], the tubers already present do not become poorer in starch when the secondary tubers are formed. The starch of the secondary tubers does not come from the original tuber, but directly from the leaves. Only in plants, whose foliage is dead, does a suddenly renewed supply of water produce secondary tubers at the expense of the starch content of the older ones. Both old and young tubers have only the starch content of the healthy tuber, which has not grown out.

So-called "water ends" are nothing but the result of a renewed growth of the apical parts of the tuber excited by a subsequent supply of water. These are thereby lengthened into a conical form and are filled with new starch (see the right side of Fig. 17). The starch filling is just as scanty as in the real secondary tuber, "Kindel."

Formation of Tubers Without Foliage.

If tubers, at the time they would sprout naturally, are not put in the earth, but are kept in a dry, poorly lighted room until the next period of harvesting, a number of small tubers will sometimes begin growth. These stand either close against the mother tuber or hang from short stolons, which have developed from the eyes. While, with a timely supply of water and light, these eyes would have grown into leaved, green sprouts, in the dry, dark store-room, the sprouting eye has developed into a thread-like runner *(stolon)* beset with scales instead of leaves, the tip of which has thickened into a tuber.

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1 Zeitschr. d. landw. Centralver. der Prov. Sachsen 1868, p. 322.
2 Annalen des Mecklenb. patriot. Ver. 1868, No. 39.

Aërial Potato Tubers.

When tubers are not planted deeply, nor hilled up, the plant remains green, while the root is liable to be greatly injured by drought or animals. If subsequent rains cause the weakened roots to function sufficiently to keep the aërial axes alive, small, colored tubers are developed on them from the lateral eyes. This process is possible also under different conditions, yet the root must be diseased and able to convey only very small amounts of water from the soil to the leafy stems. If cuttings are taken from the older parts of the stem, they can be forced to form tubers in the leaf axils.

Premature Ripening of Fruits.

In years of continued drought, as, for example, 1904, complaints become most numerous that fruit does not keep. Summer fruit indeed ripens more quickly and can be brought to market one to two weeks earlier, but the flavor leaves much to be desired. Winter fruit remains smaller, as a rule, is less juicy and well-flavored and decays more quickly, or it needs a much longer time in storage in order to become fit to sell. The former may be observed with light soils, the latter has often been found[1] when, with heavy soil, rains occur after a period of drought, causing a further growth of the fruit which, until then, had been retarded by a scarcity of water.

The condition here pictured is explained in the discussion of the fact that the quality and keeping qualities of the fruit depend upon two factors. First of all, each fruit must have sufficient time for the penetration of the water and food substances necessary for its maturity; this takes place at the time of swelling. Then the oxidation processes of ripening set in gradually, in which the reserve material, stored in the form of starch, is used up in respiration. The longer time the fruit has to store up the material supplied by the leaves, the better provided it is for the process of ripening and the better are the keeping qualities. If this process is interrupted ahead of time by drought, the processes of ripening, the conversion of starch into sugar, find comparatively little material present. In normal summer weather, i. e., alternate sunshine and rain, the fruit during the process of ripening also takes up mineral elements besides water, as Pfeiffer and I have proved. An absolute increase in mineral substances takes place shortly before complete ripening. This naturally appears relatively small in comparison with the greater increase in organic substances. With a continued scarcity of water this increase does not take place and the fruits quickly use up the scanty materials. The acid store is scanty, the formation of sugar still less, which accounts for the insipid taste and the poor keeping qualities.

In winter fruit, processes of ripening are completed only in storage. But in all other respects the same point of view holds good. If the weather during the summer is favorable for the absorbing of large amounts of re-

[1] Monatsschrift für Pomologie und praktischen Obstbau von Oberdieck und Lukas, 1863, p. 272.

serve substances, the fruit is well prepared for storage and keeps sound a long time. If the reserve substances are scanty, the fruit rapidly spoils. In seasons after a long period of drought, which has practically stopped the development of the fruit, if a time of continued cool, dry weather comes, the fruit may start its growth again and renew its life processes. If the fruit must be harvested in the autumn, it is put into storage in a comparatively immature condition and thus needs more time to become ripe. These are the cases (on the whole less frequent) in which the fruit must lie disproportionately long in storage and does not become mellow, but remains tough.

Rusty Plums.

Fox red discoloration of plums setting in some weeks before the normal time of ripening is a phenomenon of premature ripening. The fruit is still absolutely hard and, on an average, about half as large as that normally ripened. As a rule, the rusty plums fall prematurely. The phenomenon occurs only in continued hot, dry periods and is found especially on sandy soils. This discoloration occurs at different times for different varieties and is similar to the premature coloration, which takes place in wormy or otherwise injured fruit. It should be emphasized that the dry locality itself is not the cause of the rustiness of the fruit, but it is due to a scarcity of soil water succeeding a period of normal precipitation. Trees whose water supply is scant, adjust themselves to conditions by dropping the fruit, which they cannot develop, shortly after blossoming. The disease only appears on those trees which have held their fruit until summer under normal moisture conditions, which are then followed by a long, dry period. An abundant supply of water must be provided to overcome this, and should not be too long delayed, else not only the rusty fruit but often all the fruit, will fall.

Further Phenomena of Premature Ripening.

As a matter of course, the results of continued soil dryness after a normal spring moisture are observable in all kinds of fruit. The dropping of leaves and fruit is of frequent occurrence. The scanty maturing of the organs remaining on the plant is a less common phenomenon. This produces also poor keeping qualities in stored fruits and potatoes and small grains in the cereals. We will return later to the discussion of other cases, when we consider the results of unusual dryness of air.

Mealiness of Fruit.

Especially in hot summers on sandy soils it has been observed that fruit, especially early varieties, does not become juicy and crisp, but is tought, poor in sap, insipid rather than aromatic in taste, and when put under pressure, makes a mealy paste. In cooler years and in other localities even the same varieties do not become mealy, but change at once a firm condition to a liquid, winey, doughy or a decomposed condition.

I know of no special investigations of the case at hand. On this account it can be stated only hypothetically that the mealiness of the fruit depends upon a definite act in the ripening process, which has been directed into other channels because of the scarcity of water. This change in direction might not be associated with the connection of the fruit and the tree, but may set in late in the development of the fruit, about at the time when the intercellular substances generally dissolve. In normal ripening of fruit, after passing the stage of great sweetness, in which the fruit is already "mellowing," i. e., the cells of its flesh are easily separated from one another, there occur at the expense of the sugar first an alcoholic and finally an acetic acid fermentation. The fruit becomes *winey and doughy* with a constantly advancing oxidation or browning. According to Fremy[1], a part of the alcohol thus formed is combined with the fruit acids to form the ethers, which condition the flavor of the fruit. A cool temperature prevents the rapid oxidation of the sugar. The supply of water from the branch to the fruit, becoming less with ripening, explains the fact that, in great summer heat, the fruit develops with extraordinary rapidity and in this gives off carbon dioxid and water abundantly. In fruit, however, the flesh is poorer in water and is very easily warmed through; the reduction of the intercellular substances, which we reckon among the pectines, cannot take place in the usual way. A. Mayer[2] considers the pectines as condensation-products of *Galactose* and the pentoses, *Arahanose,* and calls attention to the peculiar fact that they are jelly-like because of a special enzyme and are hydrolized by another to the pentoses. It may indeed be assumed that these processes are changed quantitatively and qualitatively when the fruit becomes mealy. This is indicated by the circumstance that in mealy fruit a firm connection always exists between the outer skin and the flesh of the fruit, while in the normal winey-doughy condition the outer skin can be raised easily from the flesh, i. e., the intercellular substance is dissolved. The insipid taste of mealy fruit is explained by the scanty content of acid and the quick destruction of the sugar.

When establishing the theory that an excess of warmth can cause a relative lack of organic acids in fruit, attention must be called again to the fact that the acids formed in the leaves during the night are in great part used up again during the following day. This process of oxidation will also take place in green fruit and it is indeed conceivable that in the long, hot summer days, this is so intensive that a large part of the acids already produced disappears. Under such circumstances no vinous fermentation takes place.

The fact that I was able artificially to produce the mealy process in apples favors the theory that the mealiness of fruit appears with the scarcity of water in the cells and a pasty decomposition of the cellular substance, if the conditions necessary for a vinous fermentation are not present. Fruit of various sorts was packed in layers in dry sand after ripening normally

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[1] Compt. rend. LVIII, p. 656.
[2] Agrikulturchemie, 5th. Ed. Vol. I, p. 141. Heidelberg 1901.

on the trees and was kept from autumn until the next summer in a cool, light cellar, in order to let the fruit mature as slowly as possible. In this it was proved that some fruit with an absolute uninjured wax coating was still sound in August, but absolutely insipid in taste and of a mealy consistency[1].

Bitter Pit.

In the flesh of fruit, especially of apples, brown, tough, scattered spots are produced, which sometimes taste bitter. If these are found just beneath the skin they become noticeable as somewhat depressed tough places, which, at first paler in color, finally become brown. The phenomenon is most frequent with porous soil in dry years, such as 1904. The firm fleshed varieties suffer less. Although a fungus *Spilocaea pomi* Fr. is given by some investigators as the cause, I still would like to consider the phenomenon as the result of a too rapid maturing in individual cell groups in the flesh. In each fruit the tissue of the flesh seems unequally filled with reserve substances. If premature dryness of the soil prevents the accumulation of the proper amount of organic material for the complete maturity of the fruit, different tissues will remain especially poor in contents and actually complete their life

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1 In mealy fruits, as well as in those normally juicy, the state of ripeness is characterized by the appearance of peculiar substance groups becoming visible immediately after the sections have been put in undiluted glycerin.

The adjacent figure shows a cell from an apple (**Gloria mundi**) when the section had been placed immediately in glycerin. The delicate plasmatic primordial utricle which had been contracted into folds is partially omitted in the drawing. The content is pushed together more or less. Also the very large vacuole at once noticeable in most cells, usually lying in one corner (which I would like to call an acid vacuole), is omitted in the illustration so that the substances appearing with the glycerin reaction may be more clearly apparent. Emphasis should be laid upon the fact that all cells do not show this response. The outer flesh of ripe apples, pears and peaches reacts especially well. The investigations indicate that a substance closely related to sugar is present in the cells in various transitional forms. This substance is found between isolated larger vacuoles or the numerous very small ones; it might be imbedded in the cytoplasm or be free in the cell sap, either as separate cloudy drops or in rectilinear masses which, from their appearance, may be dough-like in consistency. Often they are found in more strongly refractive and solid forms as tuberous, warty, irregular growths. This most solid state appears also in the form of very small, sandy grains imbedded in the cell wall, attention to which is first called when they swell up to drops or (by forming vacuoles) to small bubbles in the glycerin. All three forms have a capacity for swelling in glycerin. When observed under water, the drops become indistinct and disappear, but in extracted apple juice they remain visible and may be distinguished from the different vacuoles. The radiating middle structure of the figure shows the most marked results of the swelling, while the doughy condition of the substance is indicated by the shaded surface with curved outlines lying below this. The surroundings represent the part of the cytoplasmic sack, which lies in the same plane and which encloses the grains of coloring matter and two vacuoles.

The process of swelling is the same in the three masses described above, but occurs in different intensities. It appears most rapidly and furthest developed in the drop form and decreases the firmer the substance becomes. With the addition of water the drops disappear first, in their place there remains at times a finely ground residue at the edge of the cytoplasm; somewhat later the doughy masses become invisible and the dividing line formed through the cytoplasm becomes circular. The polyp forms become slowly transparent; the warty masses gray grained and cloudy without dissolving entirely in one day. If, at the beginning of the entrance of water, cloudy balls, generally lying along the walls imbedded between the vacuoles, are observed, there is frequently noticed a swelling of different groups of cell contents beginning at the inside, which increases up to the formation of vacuoles. A similar phenomenon is found with glycerin where the process sets in more slowly and the changed conditions are retained longer. By this process of swelling of the substances imbedded in the cloudy drops, the inner part of these appears at times filled by one or more vacuoles in such a way that an actual cloudy mass occurs only as a slender ring enclosing the vacuoles. This becomes more and more

cycle so much the more quickly. The beginnings of the disease must be sought in a rather early stage of the fruit's development. I often found in diseased cell groups, recognizable by browned and corked membranes, many grains deposited on the cell wall. These slowly colored blue with iodine and therefore must be spoken of as starch. Some of them showed a warped seam which remained whitish. Further, a splitting of the browned tissue is observed often in the tough fleshed early apple, varieties which are most inclined to become specked. These splits are explained by the fact that when

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transparent in water until it can no longer be recognized. No actual dissolving of the substance has been observed. If fresh sections are laid first in water, cloudy drops do not appear, from which it may be concluded that the substance is taken up by the water. Indeed, in several cases, it was observed (in Reinettes) that if the drops had disappeared after a rapid temporary action of the water there was left a fine grained residue. With the addition of glycerin the solid grains either form drops or separate filament-like pouches. Perhaps it is only these grains which, imbedded in the drops and the remaining, above-mentioned forms claimed to be different aggregate conditions of some ground substance, swell up to polyp-like radiations. It is seen especially in the drops which are enlarged to a thick-walled vesicle by a vacuole that only some places may be elongated like pouches or chains of beads which in individual cases can reach the wall layer and thus transverse the cell as knotted bands. With the continued slow swelling in glycerin the figures change constantly whereby the substance, which becomes more and more doughy, more weakly refractive and stringy, shows an attempt to return to the drop form. Either some of the chief arms of the above represented polyp-figure take up more and more substance and become broad bands which finally draw together into spherical drops, or separate beads of the chain show a stronger growth with a constant increase in size and decrease in refractive power, whereby the smaller spherical links of the chain and the thread-lke substance possibly connecting them becomes more slender, finally tearing apart and becoming drawn into the larger drops. In most pronounced cases these drops were recognizable after 96 hours, but later could no longer be found nor produced again by reagents.

Fig. 18. Parenchyma cell from the flesh of a ripe apple after treatment with undiluted glycerin. (Orig.)

The reason that I place the substance mentioned in the list of sugars, or between sugars and ferments, is their occurrence in the same cells, which contain large, strongly refractive drops capable of being drawn together by glycerin, or separated by alcohol and showing a copper reaction into which it seems to me pass over the small, above-mentioned drop forms. The large syrup drops which may be drawn together in certain parts of the cytoplasmic sac by glycerin and which gradually disappear again, may be partially fixed by the use of the potassium bichromat since a persistent brown-grained precipitate is formed. In pears I found this phenomenon after the action of dilute sulfuric acid on the glycerin preparation in which the walls of the stone cells became the color of wine. Ferric chlorid gives no special color reaction. If a piece of caustic potash is put in the glycerin preparation the syrup balls color an intense yellow and the remaining cell content a lighter yellow. Chemically pure grape sugar behaves similarly but, dissolved in pure water, it gives only a weakly yellow liquid. The addition of calcium chlorid or calcium nitrate will hold the drops in form somewhat longer. They then retain their strong refractive power from 2 to 4 days. With the use of silver nitrate a brown grained precipitate is produced in many syrup balls, which consists either of many very small grain bodies or less numerous larger tuber-like ones. A part of the drops disappear without giving any precipitate.

It seems to me that we are concerned here with an extremely easily changed substance, easily soluble in water and alcohol, but less soluble in glycerin, which occurs in the same cell in different transitional stages, thus howing different reactions Even exposure to the air brings about a change, since an apple, which shows a quantity of drops on its freshly cut surface, does not show any drops on this same cut surface after a few hours when acted upon by glycerin, and these may only be found again deeper in the tissue.

the fruit was attacked by the disease, while the cork layers were swelling, the specked tissue had already lost its elasticity.

The dying of single tissue groups of this kind as the result of an insufficient storage of reserve substances will take place so much the more easily as the deposition of starch is made more difficult by the one-sided increased nitrogen fertilization. In fact, practical fruit growers have also observed that this specking is especially abundant, if the trees have been excessively fertilized with sprouted malt, hornshavings, etc.

Wortmann[1] substantiates our theory in regard to the non-parasitic character of the specks and of their occurrence with a scarcity of water. He ascribes the appearance of the dead cork cell groups to an excess of acid which is brought about by the concentration of the cell sap of the fruit as a result of unreplaced water loss. The absolute acid content decreases with the ripening of the fruit, but the relative acid content becomes increased with scarcity of water in the cells. Wortmann concludes from his investigations of the epidermis that the larger fruits evaporate more than the smaller ones and the specked varieties (reddish Reinette, Goldgunderling, King of Pippins, Landsberger, green Stettiner, Danziger) evaporate more than do the varieties not inclined to specks. He found a greater thickening of the outer walls of the epidermis in the non-specked varieties, the peeled specimens of which evaporated more than did peeled specked apples. If the fruit of non-specked varieties was pricked with a needle and laid in acid or alkaline solutions (potassium, tartarate, limewater) specks were produced which could not be distinguished from natural ones.

The phenomenon of the so-called "fly specks" should not be confused with this. Very fine little black points united into groups are found on the apple peel, which appear to the naked eye like a cloudy bloom and under the microscope look like accumulations of fly specks. Fungi, especially *Leptothyrium pomi* Mntg. and Fr. and *Phyllachora Pomigena* (Schw.) Sacc. are given as the causes. Often actual insect secretions are found in which fungi grow. Since the skin under the "fly-specks" does not seem to have been injured in any way, rubbing with a damp cloth is enough to make the fruit again fit for sale. Another phenomenon, often called specking, is the *"rusting of the peel."* This term comes from the change in color of the outer skin. During the *process of swelling,* the skin gets stellate or dentritically-branched tears, which are closed by the formation of cork.

Stoniness of Pears and Lithiasis.

When pears are grown on poor soils, in dry years the flesh is solid, but grates between the teeth when eaten, in wet years the flesh is tender and does not grate between the teeth. This grating is due to the extraordinarily large amount of stone granules formed in the years of drought. Practical workers often maintain the theory that the formation of stone cells in pears is the direct result of great drought.

[1] Wortmann, Jul., Ueber die sog. Stippen der Aepfel. Landwirtsch. Jahrbücher 1892, Parts 3 and 4.

Investigations of young fruit show, however, that in each variety of pear in normal development aggregations of coarse-walled schlerenchymatous cells are always present unequally distributed. These stone cells are in fact an anatomical characteristic differentiating pears and apples[1]. Therefore, it is not the occurrence of the stone cells but only the greater thickness of the walls already formed which is the result of the drought. In many varieties they remain relatively thin-walled. To this should be added that their connection with the surrounding tissue is tougher and closer in dry years.

In the so-called stoniness of pears, only the increased wall-thickening[2] of the normally deposited schlerenchyma cell centres is concerned and therefore no increase of the elements, while we find in Lithiasis an accumulation of stone cell elements produced subsequently by cell increase. These finally may also extend over the surface of the fruit and then form light brown circular specks, either equally distributed or clustered on the sunny side or even map-like etchings due to the running together of the specks (Fig. 19), the upper surface of which shows a crumbly construction. Not infrequently the same varieties of pear suffer also from Fusicladium (see Vol. II). Nevertheless, the Lithiasis specks may be easily distinguished from the smooth, usually blackened, fungous specks, because of their crumbly constitution and the raised edges of the wound.

Fig. 19. Pear diseased with Lithiasis. (Orig.)

So far as observations have shown as yet, only certain varieties suffer from Lithiasis. Many, in fact, form predominantly roundish specks, while in others usually zigzag gapping cracks are produced. Stone masses are not always depressed, often they occur on the upper surface as pale cork-colored cushions.

An entirely normal construction may be found in the healthy parts of the pear attacked by the stone disease; i. e., underneath the small celled, not

[1] Turpin, Memoire sur la difference qu'offrent les tissus cellulaires de la pomme et de la poire etc. Paris. Compt. rend. 1838, I, pp. 711 ff.

[2] The substance, of which the stratified thickened walls of the stone cells consist, has received the name of glycodrupose from Erdmann*. He used this name because he thought that the chemical composition of these cells is the same as that of the tissue of stones of plums and cherries (Drupaceae). The substance, decomposed by moderately concentrated hydrochloric acid, gives half its weight in grape sugar in solution. The half remaining undissolved is called drupose; when boiled

very thick-walled, colorless epidermis (Fig. 20 *e*) lie three or four layers of usually tangentially elongated or cubical parenchyma cells (*p*) which are richer in cytoplasm than the deeper lying tissues and contain chlorophyll, but no starch. The starch is found to appear gradually first in the inner flesh and its grains usually increase in size toward the core. Underneath the outer cell layers, rich in chlorophyll, the deposition of the stone cell centres begins (*st*). These form groups of a few cells in the normal flesh; in the coarse fleshed fruit they are separated only by small intermediary areas of delicate parenchyma (*zp*). From the periphery toward the interior of the fruit, the stone cell groups become more scarce and the surrounding parenchyma assumes a stellate arrangement.

In the first stages of the disease, we find in fruit, which is always green and hard, that, underneath the uninjured and colorless epidermis, individual cells contain no chloroplasts, but have a brown, strongly refractive cell content, which is massed together in lumps. The number of these browned cells gradually increases and ruptures the outer skin. Beneath the ruptured place which, by the drying and crumbling decomposition of the tissues forms a depression (*gr*), a brown-walled dying tissue (*br*) is found in the midst of the flesh, which later may rupture and form cracks. Often in these cracks, and always in the open peripheral pits (*gr*), may be found a colorless slender mycelium which is a subsequent infection and may hasten the decomposition of the tissues.

A most striking phenomenon is the fact that when the pit has been formed the flesh tissues no longer die and closed masses of newly formed schlerenchymatic tissue begin to push out like cushions with a radial structure (*f*). These cushions of stone cells force the dead bark (*t*) tissue out and off.

In cross-section the individual elements of the stone cell cushions are square or rhomboid, and lie almost unbrokenly upon one another. Even in

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with nitric acid and washed with water, ammonia and alcohol this leaves behind a yellowish white cellulose. Erdmann concludes from his investigations that the substance of the stone cells may be produced from a carbohydrate by the loss of water and nitrogen from starch or gum, while in the normal process of ripening, water must be taken up for the formation of the sugar.

The theory that the formation of sugar and of cellulose are most closely connected is given expression by DeVries**. He says that usually an accumulation of grape sugar is found in those young cells which later strongly thicken their walls. For example, the bast fibres of clover as well as fibres of the inner fibrous sheath of the vascular bundles, which appear to be very thick walled in a mature condition, are rich in grape sugar in their younger, still thin walled stage, while the surrounding tissue is poor in sugar or lacks it entirely. DeVries found the same conditions in the young bast fibres of potato and maize. Even in the hairs, which are thick-walled later, an accumulation of sugar takes place before the thickening of the walls, thus, for example, in the hairs of young clover leaves, in whose parenchyma, however, no sugar could be proved. In the same way, according to DeVries, sugar can not be found in the root parenchyma of this same plant, while in the young root hairs it occurs abundantly. The possible transversion of cellulose to dextrin and sugar by the action of dilute sulfuric acid after heating is well-known. With this the recent investigations on the Hemicelluloses; mannen, galactan and araban, should be compared.

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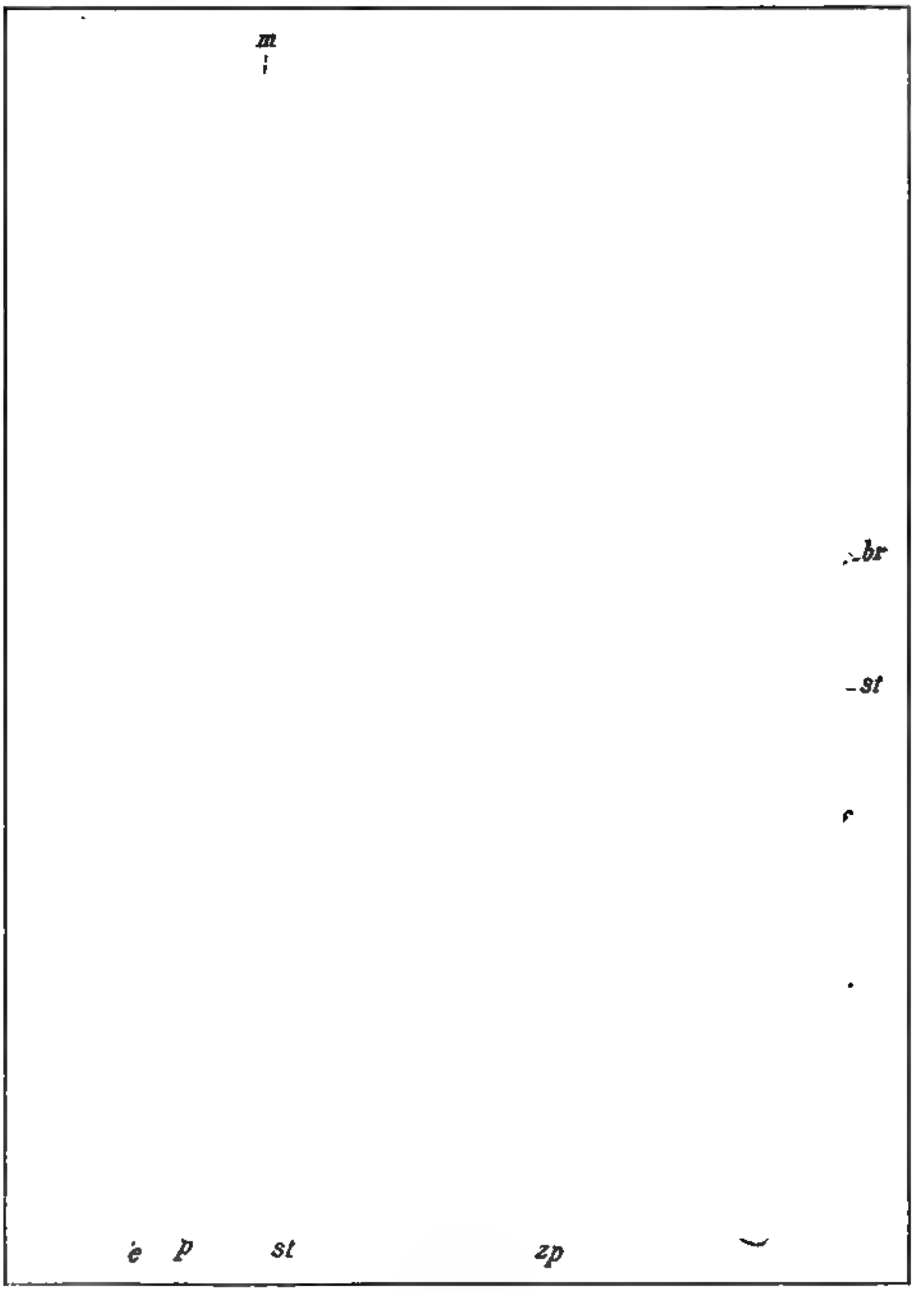
* Liebig's Annalen, Vol. 138, p. 101; cit. im Jahresbericht f. Agrikulturchemie 1866, p. 99.

** Wachstumsgeschichte der Zuckerrübe, in den Landw. Jahrb. 1879, p. 438.

early stages they color a bright yellow with Anilin sulph. and when oldest will dissolve easily in sulfuric acid without any observable precipitation of gypsum crystals. While the normal stone cells usually remain yellow



Cross-section of a stone cell cushion from a pear diseased with Lithiasis. (Orig.) Explanation in text.

from the effect of *zinc iodid of chlorid,* the elements of the schlerenchyma cushions, which were formed later, turn blue after some time, either throughout or in the innermost lamellae of the walls.

The growth of these schlerenchyma cushions takes place in a meristematic layer (*m*) formed underneath the dead bark and appears at first as if it would develop into a flat cork layer, cutting off the centre of the diseased tissue, as may be observed in the Fusicladium cushions. This, however, is not the case. The meristematic layer is active as long as the fruit is green and growing. Toward the periphery it forms new thin-walled bark cells (usually in small numbers) which again are gradually attacked by bacteria and fungi, while on its inner side, toward the (usually seedless) core, the thick-walled elements of the stone cell cushions are increased.

The radial arrangement of the cell rows in these is explained by the tension of the tissues which the swelling of the unripe fruit causes. If, in this, the new formation of stone cells is greater than the distension of the parenchymatous tissue of the fruit flesh, the stone cells are pushed out like cushions. As a rule, however, both processes keep step and finally, by the death of the pathogenic meristem itself and the breaking of the connection between the outermost stone cells, is produced the crumbly constitution of the stone spots.

It is a matter of course that fruit attacked by Lithiasis is unfit for consumption.

Since this phenomenon is not found in all varieties, and not every year even in the same varieties, but is a destructive factor only on dry soil in dry years, the supposition, that the stock used in grafting influences the problem, seems probable. Weakly growing stock which cannot take up sufficient amounts of water from a dry soil for a rapidly growing top, because of its small root area, will favor this stony condition. If, on this account, the disease should occur repeatedly in the case of dwarf trees on light ground, an attempt should be made to graft pears on the most rapidly growing varieties of quince. When standard trees are in question, an attempt to overcome the difficulty should be made by renewing the soil, fertilizing the sub-soil and watering abundantly; in obstinate cases, by means of renewal of the top by pruning after fertilization. Some method of forcing the fruit to swell as rapidly as possible might best protect it from an excessive formation of stone cells.

Varieties of Fruit Suitable for Dry Soils.

The guiding idea of our manual is that many diseases of cultivated plants may be prevented by a more careful consideration of the relation between the character and habits of the plant and its environment. In accordance with this plan in treating diseases favored by drought, we mention a number of well-known varieties suitable for dry soils[1].

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1 Oberdieck, Deutschlands beste Obstsorten, Leipzig, Voigt. 1881. L. indicates that the variety is recommended to the agriculturist. Str. suitable for planting along streets. The name of the month after that of the variety indicates the time of complete ripening.

Apples: Summer Rose, End of July. L. Str., Scarlet Pearmain, Autumn. L. Str., Landsberg, Autumn. L. Str., Dantziger, Autumn. L., King of Pippins, Winter. L. Str., Orleans, Winter. Str. (For the agriculturalist where the soil is better), Yellow Bell flower, Winter. L. Str., Alant, L., Deutscher Gold Pepping*, Winter. L. (must be left on the tree until the middle or end of October), Kassler, keeps from winter until summer. L. Str., Purpurroter Cousinet*, winter till summer.

Pears for dry soils: Hannoversche Jakobsbirne*, end of July. L. Str., Clapp Favorite. August. L., Archduke, August. L., Yat, beginning of September. L. Str., Kuhfuss*, beginning of September. L. Str., Treyve, September. Autumn Melting (Downing), end of September. L. Str., Bosc, end of October. L., Marie Louise, beginning of November. L. Str., Mecheln, December. Madam Korté*, January. Kemper, cooking pear for the whole winter. L. Str.

Cherris, as is well-known, prefer a well drained, dry soil; on the other hand, *plums,* on the average, flourish best in a moist, heavy soil and also they bear sweeter fruit. It is desirable to know a number of varieties requiring less water. Biondeck, beginning of August; early Apricot, middle of August; Lawson, end of August; Bunter Perdrigon, end of August; Berlepsch, beginning of September; Altham, beginning of September; Jerusalem, beginning of Septembr; Anna Spath, middle of September; German prune, end of September. As a street tree, the plum is not very desirable because of its habit of growth.

As varieties which grow well on dry, light soils in the climate along the coast, should be mentioned[1]: 1. *Apples*: Landsberg, Purpurroter Cousinet*, Oldenburg, Geflammter Kardinal*, Bauman; the Prinz (Downing) is especially suitable for the provinces along the Baltic and the North Sea. 2. *Pears*: Yat Bosc, Red Bergamot, Summer Doyenne. 3. *Plums*: House Plum. 4. *Cherries*: The common sour cherry.

Stunting.

Since almost everywhere in nature similar effects are obtained by different means, a limited soil space may be only one cause of dwarf growth; another is the *lack of available nutriment* due to either a scanty supplying of raw soil solution to the roots or to the decrease of organic reserve nutriment. This latter case we will have to consider again later in the "Pincement Grin," i. e., in the pruning of leaves to prevent the sprouting of the buds found in their axils and in the production of dwarf seedlings by cutting off the cotyledons which are rich in nutrition.

In nanism, however, caused by soil physically unfit because of too great porosity, water scarcity alone must be considered. Given a soil rich in mineral or organic food substances, the size of the plant depends upon the distension

* Name of variety given in the German original, not reported in the United States of America.

[1] From a written communication of Mr. Klitzing (owner of a nursery) in Ludwigslust.

of the individual cells, due to the turgor produced by the water from the roots, and the conclusion is at once reached, that a scanty supply of water during the time of growth must produce small dwarf specimens. Each excursion through sandy regions, in which a damp subsoil is either lacking or lies very deep, furnishes examples enough for this fact. I have published detailed measurements concerning the shortening of cells due to a scarcity of water[1]. Möller[2] furnished experimental proof of dwarfing due to scarcity of other food substances with an excess of water and also confirms the principle that in slightly concentrated nutrient solutions the root increases relatively in size. Möbius[3] has arrived at the same result in his comparative cultures with Xanthium in sand and loamy soil. He found the roots and stalks of plants grown in sand branched more than those of plants grown in loamy soil, while the leaves were more slender and the glandular hairs fewer in number. On the other hand, in plants grown on loam the content of calcium oxalate crystals seemed smaller. The thorns were smaller on sandy soil, but the walls of the lignified cells seemed considerably thicker.

Comparative studies of the influence of dry or wet localities were made by Duval-Jouve[4]. These proved that in dry, hot places, a formation of the hard, bast bundles is especially favored, but is retarded in shady, wet positions. Volken's observations[5] on *Polygonum amphibium* in the forms grown in sand, heath and water, are very thorough. In the sand form the circumference of the stem is smaller, at the expense of the central air canal; the bark cells are more heavily thickened, while between the bark and the phloem, a rather broad ring of uncommonly thick mechanical cells is enclosed. A closed wood cylinder is formed, the vascular system in which is almost 2 to 3 times as strongly developed as in the water-grown stem; in the latter, the absence of thick-walled elements and the occurrence of large air holes facilitate floating. The petioles of the water form, which have no mechanical reinforcement, may become six times as long as in the land form, the midribs of which are strengthened by strong collenchyma cords. The palisade cells are more strongly developed in the water plants, but these lack, on the other hand, the strongly developed bristles on the upper surface and here also the somewhat larger epidermal cells which in the land form contain a slimy content, explained by Volkens as a water reservoir in times of great drought. In the well-known Rose of Jericho *(Anastatica hierochuntica)*, that plant of the desert which closes together like a head when dry, the inclination of the branches toward each other arises from the fact that the wood cells on the different sides of each branch possess a different capacity for swelling longitudinally, which goes hand in hand with an unequal lignification.

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1 Sorauer, Bot. Zeit. 1873.

2 Möller, Beiträge zur Kenntnis d. Verzwergung. Landw. Jahrb. 1893, p. 167.

3 Möbius, M., Ueber den Einfluss des Bodens auf die Struktur von **Xanthium spinosum** usw. Ber. d. Deutsch. Bot. Ges. 1905, Vol. XXII, Part 10.

4 Duval-Jouve, Anordnung der Gewebe im Blatte der Gräser. Bot. Jahresb. v. Just 1875, p. 432.

5 Volkens, Beziehungen zwischen Standort und anatomischem Bau der Vegetationsorgane. Jahrb. d. Kgl. Bot. Gartens zu Berlin. Vol. III, 1884, p. 46; cit. Bot. Centralbl. 1884, No. 46.

From the beginning one must note that every limited supply of nutriment which leads to nanism must express itself mostly in the amount of additional growth, i. e., in the formation of the secondary tissues. An anatomical proof of this has been furnished by Gauchery[6], who cites cases when the cambium has formed anew only a few rows of cells. Often he could no longer determine any meristematic zone whatever between phloem and xylem; therefore, the original cambium must have passed over at once into permanent tissue as the result of deficient nutrition.

In the plants which are forced to grow in sandy or stony soil, often with a lack of water, a form of *hyperplasia*[1] (arrested developments) appears. It is not so much the number of the cell elements which seems to be decreased, as their size. Thus specimens are formed which we would like to call *"stunted plants."* By this is understood woody plants, the growth of which is not retarded to dwarfing but which, by the striking shortening of their axial organs, show a repressed, knarly habit of growth.

In this habit of growth the very evident, increased *spiral twisting* of the woody elements of the trunk counts as a typical characteristic. The finest examples are seen in Syringa and Crataegus. We can explain the production of the increased spiral twisting if we think of the direction of the woody cells as the diagonal of the parallelogram of two forces.

At the apex of each elongating axis there is, on the one hand, an effective striving toward growth in length in which the elongation of the pith body becomes a decisive factor of swelling; on the other hand, the general enlargement of the young cells acts also as the cause of the radial enlargement of the trunk. In considering a very young wood cell in the cambial layer, stretching longitudinally, we see that, as the growth in length predominates over the growth in thickness, it is relatively difficult to divert the cell from its longitudinal growth. However, as the abundantly formed young wood cells, during elongation, are pressed outward by the growth in thickness of the medullary cylinder in the direction of the radius of the trunk, proportionately just so much the sharper will be their spiral twisting. On this account we find long slender shoots with a slight spiral twisting in plants on moist nutrient soil, and on sandy soils poor in water, or with other checks to growth in length, plants having short axes with strong twistings.

Confirmation of the hypothesis is found in the *"enforced twisting"* to be mentioned later. The more the stems are distended like barrels, the sharper is the spiral twisting of the cords of the leaf spur.

We mention this point because the occurrence of such strongly twisted stunted plants is valuable as a symptom in judging the soil conditions.

Pilosis.

Plants grown on dry soil soon have a hairy appearance, even if no more hairs are formed than on specimens of the same variety growing in damp

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[6] Gauchery, Recherches sur le nanisme végétal. Ann. sc. nat. Bot. 1899. VIII. sér., t. IX.

[1] Küster, E., Pathologische Pflanzenanatomie, Jena 1903, p. 21. Here abundant bibliographical citations.

places. If a definite number of hairs are formed on a leaf, these are closer together in a given small area, because the epidermal cells separating them are shorter. This partially explains why alpine plants appear to be less pubescent when grown on plains. These plants grow more luxuriantly, the dimensions of their organs become larger and the hairs are separated further from one another. But, in fact, even in dry localities, an increased hair formation takes place. Thus Moquin-Tandon[1] cites observations by Linneus, that the Lady's Thumb *(Polygonum Persicaria* L.*)* seems very smooth at the edge of bodies of water, but beset with hairs in dry places. Our field thyme *(Thymus Serpyllum* L.*)* loses its glaucous surface at the sea shore and acquires a short, hairy covering. Our Turk's cap lily *(Lilium Martagon* L.) when cultivated for some time in gardens is glaucous, but becomes pubescent again, like the wild plant, when grown on poorer soil, etc. Such phenomena may be observed also in garden plants which, self-sown, grow on sandy places in the fields.

An unusual hair growth takes place, further, in many parts of plants when they no longer develop normally. According to Moquin-Tandon, the stamens of the triandrous bindweed are covered with thick wooly hairs. The stamens of several kinds of Mullen (Verbascum) behave similarly if the anthers become deformed. The peduncles of the smoke tree *(Rhus Cotinus)* are almost without hairs before blossoming and if they bear seed. If, on the other hand, the fruit does not mature, the stems of the sterile blossoms grow longer and numerous, long, violet colored hairs appear on them. The last-mentioned formation of hair does not belong among the phenomena connected with drought, but should be considered as a process of correlation. The water and nutritive substances, which should be utilized in the maturing of the anthers or seeds, are used in a greater measure for the benefit of other parts of organs, when the sexual organs are destroyed. Possibly the phenomena recently observed in *parthenogenesis* belong in part here, where the micropyle is stopped up as the result of the hair-like elongated cells of the style tissue or of the integuments[2].

Also, we find in the root system that pubescence varies according to the place where the root is kept. In the same varieties, the whole system can develop into the form of long, slender, whip-like, scantily branched, bare, or almost bare roots, if the root axis dips into water or into porous sand saturated with water. The root branches become shorter, more knarled, branched and pubescent, the drier the soil is in general;—the more, therefore, that the root is obliged to depend only on the moist air of the soil interstices. In air which is absolutely dry, the roots (according to Persecke[3]), do not develop any more hairs. If the roots are exposed to moist air, the young tips, just behind the growing apex, become very hairy, because almost every epidermal cell has pushed out into a hair.

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1 Pflanzen-Teratologie, translated by Schauer, 1842, p. 61.

2 Winkler, H., Ueber Parthenogenesis bei Wikstroemia. Ber. d. D. Bot. Ges., Jahrg. 1904, Vol. XXII, p. 573.

3 Persecke, Ueber die Formveränderung der Wurzel in Erde und Wasser. Inauguraldissertation, Leipzig 1877.

In the aërial parts of plants, which are accustomed to dry air, the degree of humidity must be strikingly low if the formation of hair is to be greatly stimulated as C. Kraus[1] states when writing of potato sprouts. In very moist air potato sprouts from the same variety are hairless, or have only a few shortish hairs. Therefore, in aërial organs, it is the influence of moist air in contrast to dry air which prevents pubescence. In roots, depending mostly on water, the same effect is obtained by a continued supply of water just as the influence of moist air favors pubescence.

An extreme formation of hair on aërial and subterranean axes is therefore the result of causes acting in the same way; the usual necessary amount of water is withheld from the plants at the stage in which they are developing.

In explaining the fact that greater dryness of the environment favors the formation of hairs, Kraus and Mer[2] have cited the phenomenon that the organ's growth in length is modified or arrested with the formation of hairs. Both investigators are of the opinion that the material saved by the arrested elongation of the cells of the axis, is utilized for the formation of hairs. Besides the examples of Rhus, etc., cited above, Heckel's[3] observations support the theory that a scanty formation of other organs goes hand in hand with a very abundant development of hairs. Heckel found specimens of *Lilium Martagon* L. and *Genista aspalathoides* Lam. with an unusual hair covering together with a reduction of the blossoming parts. Kraus emphasizes the fact that, with the decrease of growth in length, an increase in turgor takes place transversely in the whole organ (as we have assumed in the development of the pith of stunted plants) which extends to the epidermal cells and excites these to the pushing out of hairs. Vesque[4], like Mer and Kraus, states that increased transpiration favors hair formation.

Attacks of parasitic animals often excite the epidermal cells to an enormous, fine growth of hair, for example, such as mites which injure the young leaves with their mandibles and thus produce the so-called felty disease. These hair formations are described under galls. In the older mycology, such hair felts, produced by the sucking stimulus of mites, are described as fungi (Erineum Pers. Taphrina Fr., Phyllerium Fr.).

Lignification of Roots.

The lignification of tuberous roots is due to the return to the original prosenchymatous woody condition of cells in the vascular bundles which, under cultivation, have become parenchymatous. The carrot, for example, which serves us as food, descends from a plant whose root consists of a

1 Kraus, Beobachtungen über Haarbildungen, zunächst an Kartoffelkeimen. Flora 1876, p. 153.
2 Mer, Recherches expérimentales sur les conditions de développement des poils radicaux. Compt. rend. LXXXVIII (1879), p. 665.
3 Heckel, Du pilosisme déformant dans quelques végétaux. Compt. rend. t. XCI, 1880, p. 348.
4 Sur les causes et sur les limites des variations de structure des végétaux. Cit. Bot. Centralbl. 1884, No. 22, p. 259.

strong, hard, wood body with a thin, tender bark. The cells of the wood tissue, like all the other wood cells, are thick-walled, spindle-shaped and wedged between one another. In the cultivated root, instead of these wood cells, thin-walled, short cells are present, ending almost bluntly against one another and even the ducts which lie in scattered groups between the parenchymatous cells are but little lignified. The latex tubes already formed in the bark, when spiral porous ducts are produced in the wood body, have broadened like all the cells of the bark. Instead of the starch which, in the wild carrot, fills out the whole bark tissue, occurring here and there in the wood body also and increasing to 70 per cent. of the dry weight, sugar has been formed usually in good table carrots so that only traces of starch may be found. The better the variety, the less the starch content as in the Dutch pale yellow and the Duwicker carrot. Gradual transitions are found back toward the wild plant in other cultural varieties used as fodder, such as the Altringham carrot and the white horse carrot. Specimens of all varieties found on poor soil go to seed as a rule in the autumn and are distinguished by a thin, often divided, root which, because of its lignification, recalls clearly the ancestral wild carrot. The same behavior is characteristic of the turnip-rooted cabbage, Swedish turnip, radishes, Kohlrabi, etc.

These differences are best made clear by comparing the anatomical structures. In Fig. 21 is shown a longitudinal section through a two-year old wild carrot. In this figure *a* is the vertically elongated parenchyma of the pith-like central part with scattered spiral, porous ducts; *b* the xylem, made up of spindle-like wood cells together with ducts and the part of the medullary ray which extends toward the secondary cortex; *c* the cambium which has become an elongated, thin-walled parenchyma; *d* the secondary cortex with its resorption spots which follow the course of the latex ducts; *e* the primary cortex; *f* cork.

Fig. 22 is a corresponding section from a two-year old cultivated carrot. The letters in both figures indicate the same parts and a comparison of the similarly designated tissues makes very clear the change in the wood tissue and the increase in the dimensions of the secondary cortex in the cultivated carrot.

In all tuberous vegetables lignification also occurs normally when they grow too old and then this process, as in individuals lignifying prematurely, is accompanied by a partial disappearance of the sugar.

It is well-known, from experience, that many of our vegetable plants lignify in hot climates. Precautions against this latter condition will be hard to find since the tropical warmth and excess of light favor rapid lignification. In cultivation in temperate climates, lignification can certainly be avoided by abundant watering and fertilizing;—only care should be taken in this that the land is deep and the seed good. Special attention should be given to the choice of seed, because seeds from dry localities carry with them a greater tendency to lignification and to a repeated division of the root.

BALL DRYNESS OF THE ERICACEAE.

The peculiar sensitiveness of the roots to drought must be taken into consideration when growing the numerous species and varieties of the Ericaceae as Erica, Azalea, Rhododendron, etc. These plants cannot endure

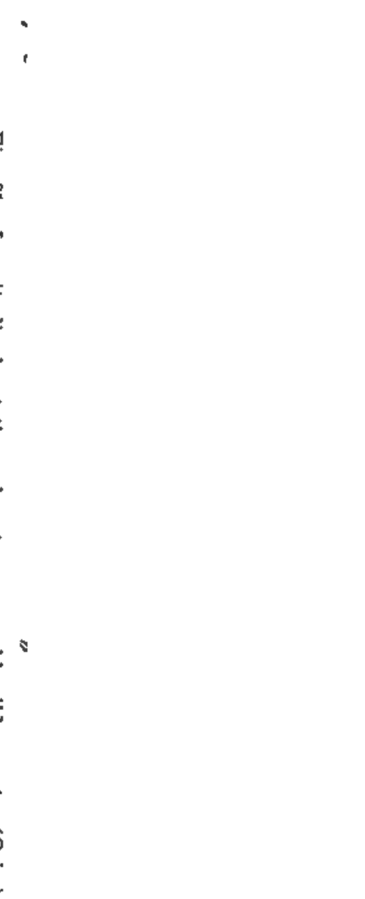

Fig. 21. Longitudinal cut through a two year old wild carrot. (Orig.)

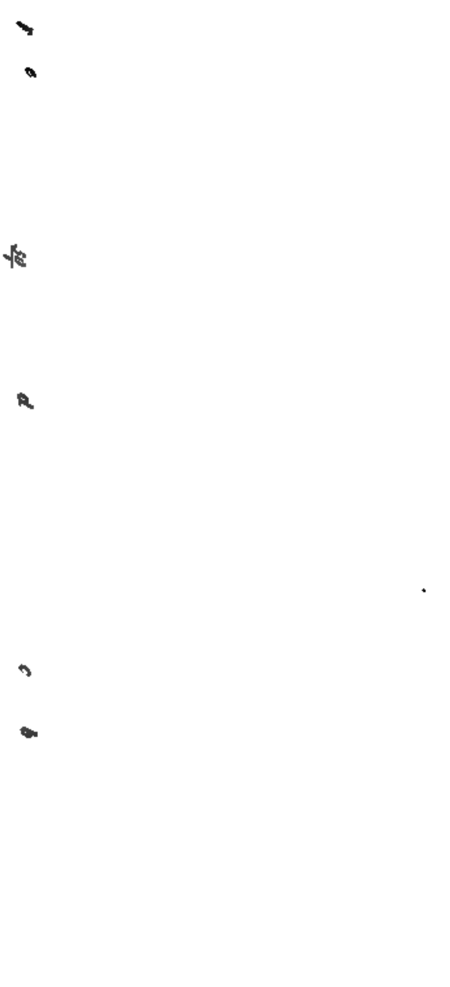

Fig. 22. Longitudinal cut through a two year old cultivated carrot. (Orig.)

a complete drying out of the roots. While other plants can survive lack of moisture, even repeated wilting, without showing any noticeable injury, and even continue growth after being again supplied with water, the fine root branches of the Ericaceae do not seem able to resume their functioning when once entirely dry. In one case I investigated the roots of an *Erica*

gracilis which, after they had dried out, had been subsequently soaked 24 hours in water, and found that the fine root ends were still shrivelled despite the soaking. The character of most Ericaceae, as moor and heath plants, is shown by the fact that (with the exception of a few varieties) they thrive best in a freely watered, easily drained, aërated soil. In growing plants in small pots the need of roots for air must be given the greatest possible consideration. The Ericas soon become root bound. The plants easily become sour in large pots. The Erica and Azalea drop their leaves when dried out. It is wrong, however, to try to repair the previous mistake by setting the pot in water and, after soaking up the earth, to place the plants in closed cases in order to reduce evaporation as far as possible and to cause turgidity. The plants should be left, on the contrary, in their customary place, but strongly shaded during the middle of the day.

Means of Overcoming Lack of Moisture in the Soil.

If a lack of soil moisture is manifested by the failure of vegetation or by its degeneration, as usually occurs more frequently in sandy soils, one naturally seeks relief in irrigation when possible. This artificial supply of water not only refreshes the tissues, but also, by dissolving the nutritive substances in the soil, it is possible for the plant to utilize and distribute these.

Irrigation.

With the frequent lowering of the ground water level, irrigation becomes a vital question and an acquaintance with the results of König's[1] investigations on the effects of irrigation water is interesting. One learns accordingly that when a meadow is being irrigated the water loses much of its nutritive material and appreciably more during the warmer seasons, than in the colder ones. This loss, however, is not true of all nutritive substances. If the carbon dioxid content of the irrigation water rises, the calcium and magnesium nearly always increase instead of decreasing. As in the case of carbon dioxid, this quantity seems to rise and to fall with the intensity of the oxidation in the soil. In contrast to the above-named nutritive substances, potassium appears to be absorbed at any time by the soil since, with irrigation, even in the winter, a slight reduction of this important mineral can be proved in the water. Sodium, or rather sodium chlorid, just like nitric and sulfuric acids almost always showed a slight increase during winter irrigation, while during the growing season they decrease, i. e., they are taken up directly by the plants.

König concludes that the oxygen of the water acts as a purifier of the soil by oxidizing the organic soil contents. This oxygen content varies according to the kind of water used in irrigation and the season. König found it greatest in spring, smallest in summer, increasing again in the autumn. Spring water is much richer in oxygen than river water which has passed through inhabited places. The opposite is true of the suspended

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1 Journal für Landwirtschaft. Jahrg. 1880. Vol. 28. Part 2.

organic substances which are taken up from the soil by impoverished spring water, which has a small oxygen content, but are deposited, on the other hand, by the richly saturated river water.

At a depth of 40 cm. during the colder seasons temperature observations show that irrigated land is warmer by varying amounts, even up to 2.8°C. To this increase in temperature may be ascribed the fact that in irrigated meadows, growth begins earlier in the spring and continues later in the autumn.

König showed by an experiment in which he artificially mixed sewage with the irrigation water, how quickly the subsoil shows its absorption qualities, if the soil is not saturated and the irrigation water is heavily charged with fertilizing matter. After the water had been used once, it could be proved that the soil had taken up 84.5 per cent. of the organic substances; 74.2 per cent. of the ammonia; 81.6 per cent. of the potassium and 86.8 per cent. of the phosphoric acid. After the same water had been used twice again the presence of these substances in it could not be proved at all. Of course these figures hold good only for this experiment and vary according to the saturation of the soil and water; they have therefore, for example, no value in *irrigation with liquid manure,* in which the soils must become surcharged with nutritive substances in a comparatively short time. Nevertheless, experiments show what varied advantages can be obtained with the right use of irrigation. The importance of watering the soil artificially is becoming more and more acknowledged. The best proof is found in the transactions of the land cultivation division of the German Agricultural Society[1] in which questions referring to the direct supplying of water, *raising of the ground water level,* have already been brought up. The systems known at present have been partially explained by means of illustrations. The transactions have led to a direct commission from the Directors of the society, "that they should take up the question of the watering of land with the greatest possible energy."

Cultivation of the Soil.

At present, in large plots of land, it is possible only in the rarest cases to provide for irrigation without considerable expense and therefore cheaper, if less effective, means are more often utilized. Such resources are found in working the soil. The *breaking up of the soil* is most advisable. Some practical workers maintain that cultivating the field soil cannot possibly aid in the retention of soil moisture, but that this manipulation must rather be considered as the quicket way to remove more water from the soil. This point of view is erroneous, as is shown by many experiments. The most thorough are Wollny's[2], who has worked with control experiments and has found that if the uppermost layers of the soil are broken up, they dry more

[1] Die Möglichkeit der Ackerbewässerung in Deutschland. Arbeiten d. Deutsch. Landwirtsch.-Ges., Part 97, 1904, p. 75.

[2] Wollny, Einfluss der Bearbeitung und Düngung auf die Wasserverdunstung aus dem Boden. Oesterr. landw. Wochenbl. 1880, p. 151.

quickly, to be sure, but, by this means, save to a greater extent the water supply in the lower layers of the soil.

The warming of field soil by insolation, its aëration when winds blow over its surface and all such influences, remove the water from the upper layers of the soil to a greater extent than can be restored by capillary attraction for water from the lower layers. If now, by breaking up the surface, the interstices between its particles become considerably enlarged, the capillarity is decreased and the water no longer rises into the larger interstices of the now crumbly soil. The more quickly the soil is broken into coarsely friable pieces by *chopping, hoeing and removing* the turf, the more the drying out of the lower layers, where the roots are found, is delayed.

The opposite result is obtained by *rolling* the field land. In this case[1] most of the spaces, where capillarity did not act, are rolled close together. Capillarity at once becomes active and the upper surface remains moist for a longer time. Under certain circumstances, however, rolling may also be recommended as a means of retaining moisture in the soil. This will be expressly suitable for all very porous soils with a scanty water capacity and an abundant subsoil moisture, since, by hardening the surface, its evaporation is reduced, while the conducting of water from below is increased. In heavy soils, with a high saturation capacity, rolling would naturally be directly injurious.

Mulching of the Soil.

Instead of breaking up the soil, *its surface may be covered* with a more porous material. In this connection advantageous results can be obtained even by covering the surface with sand. This changes favorably the conditions of moisture and of warmth at the same time, for, according to Wollny's investigations[2], the temperature of the soil is considerably reduced by breaking it up, since the conducting of heat in the friable layer is decreased by the considerable amounts of enclosed air. In the same way soil provided with a sandy covering is colder in the warm seasons than uncovered soil, because the light color of the surface decreases the absorption of the heat rays, and the considerable amount of water held back under the sand is warmed with greater difficulty. If the upper surface of the soil itself dries up, its temperature must increase because the evaporation which uses up heat is at once prevented.

Breaking up the soil and covering it, therefore, modify the extremes of temperature, but are also valuable in still another way. According to Wollny (loc. cit. p. 337), it is shown that during the warm seasons considerably more water from the same amount of precipitation can filter through the soil when covered with sand than through uncovered soil. This takes place because the soil covered with a layer of sand (even if only one

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[1] Wollny in Oesterr. landw. Wochenbl. 1880. p. 214.- Nessler, Bad. Landw. Correspondenzblatt 1860, p. 230.- Wagner, P., Versuche über das Austrocknen des Bodens bei verschiedenen Dichtigkeitsverhältnissen der Ackerkrume. Bericht der Versuchsstation Darmstadt 1874, pp. 87 ff.- v. Klenze, Landw. Jahrb. 1877.

[2] Einfluss der Abtrocknung des Bodens auf dessen Temperatur-und Feuchtigkeitsverhältnisse. Forschungen a. d. Geb. d. Agrikulturphysik, 1880, p. 343.

centimetre thick) remains richer in water, i. e. becomes saturated more quickly and therefore lets more water flow into the deeper layers of the subsoil. The same result is shown by covering with ochre, such materials as stable manure, straw, tan bark, and even with stones. Soil covered with growing plants is even less pervious than the naked earth.

Some practical workers recommend the use of *peaty earth on sandy soils.* Thus Walz[1] made use of the upper layers of a peaty deposit which were 6 to 8 cm. deep and useless for fuel, in order to cover a field of poor sandy soil 2 cm. deep, in February. Later this surface which had been covered with peat and one adjoining it, but not so covered, were richly fertilized with stable manure. In the heat and drought of summer, maize planted on the field mulched with peat showed a better growth and furnished a higher percentage of yield. In the same way, later crops were found to be more luxuriant on the plat of ground mulched with peat.

The value of the peat, which Nerlinger[2] has demonstrated in exact harvest results, arises from its ability to soak up and retain the fertilizing substances which otherwise, in sandy soil, would be washed away. I have determined experimentally[3] that fertilizing makes it possible for the plants to give a better yield with less water, which explains the more favorable behavior in time of drought.

Soils With a Plant Cover.

It has already been said that soils with a cover of living plants allow the least water to drain through. This is explained by the fact that plant roots absorb the water. Comparative experiments[4] prove that the water in the soil is more quickly exhausted with a thick stand of plants, even if this exhaustion does not increase proportionately to the density of the plant growth.

From these results, the difference between a bare, broken soil and one covered with a dense turf during hot, continued dry weather, can be ascertained. Therefore, in nurseries on porous soil, it is by no means a matter of indifference whether it is often hoed or whether turf and weeds are allowed to form a dense covering. It is not a theoretical conclusion but an often demonstrated fact that occasionally *premature ripening and sterility* are produced in fruit trees, because the weeds and turf have taken up the scanty supply of water.

In forestry and trees in beds, if the seedlings do not make a dense growth, their development is threatened. Gravelly soils without sufficient humus content are also a menace for older plants from 10 to 15 years of age, especially if protection is not given on any side by larger plantations.

[1] Zeitschrift d. landw. Ver. in Bayern 1882; cit. in Biedermann's Centralbl. 1883, p. 136.

[2] Fühling's landw. Zeit. 1878, Part 8.

[3] Sorauer, Nachtrag zu den Studien über Verdunstung. Forsch. auf d. Geb. d. Agrikulturphysik, Vol. VI, Parts 1 and 2.

[4] Wollny, Der Einfluss der Pflanzendecke und Beschattung auf die physikalischen Eigenschaften und die Fruchtbarkeit des Bodens. Berlin, Parey, 1877, p. 128.

The forester considers *turfed land* as a favoring factor, since it retains the water of precipitation and by the quick evaporation withdraws the water of the subsoil. Places almost circular are sometimes found in forests about the base of the trunks where no second growth lives. This circumstance is ascribed to the reflection of the sun's rays from the smooth barked, branchless trunks (beeches, birches, firs). The sun rays flashed from the mirror-like bark dry the soil to a great extent. This condition can be overcome by various means, among which growing plants by natural seeding is recommended, since the plants so produced will adapt themselves to the locality. In places, which must be planted, material should be used which has been transplanted once in the nursery and, after the plants are set out, the soil should be shaded most carefully. Besides this, all conditions should be considered which in general may be recommended for overcoming the lack of moisture, such as the protection of seed beds by walls, fences, rows of trees, or by closely set brush, hilling and especially breaking up the soil, or even fertilizing, since this means a saving of water. Sprinkling with water is advisable only in the most extreme cases of necessity. In brushing the edges of the beds the use of conifers, especially the Weymouth Pine, is most to be recommended, for spruce brush sheds its needles too quickly and makes a warmer cover. Fir may easily be set too densely and the leaves on branches of deciduous trees wilt too quickly, hence they do not afford shade to the soil which dries out too rapidly.

Wollny has shown by experiments that *seed and turf* burn out if sown too thick, while vegetation on the same plot of land remains uninjured if the growth is more broken.

He found that when the seed had been sown with a drill the soil between the rows lost less water than that in the rows themselves and the further the plants stood from one another, the more water was retained in the rows as well as between them. Therefore, *the proper adjustment of the quantity of seed* to be sown on soils poor in water, will also assist in correcting injury due to drought[1].

Only in very definite cases can an overplanted soil be proved more advantageous than bare soil. By an open growth of short-lived *plants as a cover crop,* water can be retained on sandy soils for later seeds. If seeding of the quick growing plants takes place in the autumn or early spring, the time these plants most need water will come during the autumnal or spring wet season, so that when the dry season comes, they are ready to set fruit and require relatively little water;—rather, by shading the soil and by the forming of dew, they retain for the more superficial layers a pretty even moisture in which seeds sown later, and also delicate seedlings, can be developed which otherwise would have dried up on bare soil.

Forest Litter.

It should not be forgotten that any covering of the soil retards the aëration of the land and therefore, for the maintenance of fertility, the

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[1] Oesterr. landw. Wochenblatt. 1880, p. 233.

supply of carbon dioxid in the soil must be depended upon to disintegrate and dissolve the fragments of rock; hence great care must be used in the choice of the soil covering. How much the mulching disturbs the circulation of the air is shown by Ammon's experiments[1]. With 40 mm. of water pressure in an hour there passed through a layer of earth 19.6 sq. cm. in cross-section and 0.5 m. deep, the following amounts of air:—

With a Grass Covering.	Straw Covering.	Uncovered.
1.60 l.	6.30 l.	7.32 l.

In better aërated soils more carbon dioxid will also be produced and this, in spite of its increased elimination into the air, will make itself felt in an increased amount in the soil. The result of letting the soil lie fallow consists directly in the greater production of carbon dioxid due to the action of micro-organisms and to the greater decomposition of the rock dèbris.

Another disadvantage of mulching is the lessened availability of the precipitation for such covered soil. The amount of this disadvantage will vary according to the kind of covering. It will increase with the increased sponge-like substance of the covering. Riegler's[2] statement may serve as an example of this diversity. He tested various forest litter and peat moss (Sphagnum) as to permeability. Of the 500 g. of water, sprinkled daily in a fine stream on the air-dry litter, the following amounts were absorbed or ran throught:—

	Beech Litter		Hemlock Litter		Sphagnum Turf	
	Ran through-	absorbed.	Ran through-	absorbed.	Ran through-	absorbed.
1st day..	400.3	99.7	441.3	58.7	216.0	284.0 g.
8th day..	487.6	12.4	499.6	0.4	493.5	6.5 g.

This sprinkling corresponded to 10 mm. of rain and accordingly possibly 20 per cent. of the falling water was retained by beech litter, 12 per cent. by fir and 57 per cent. by moss. The mulch was 8 cm. deep all over. From Riegler's other tables it is found that, in the next 3 or 4 days, still greater amounts were absorbed daily, gradually up to the 9th day the litter became so saturated with moisture that almost all the water which fell upon it ran off. Ten mm. of rain setting in after hot, continued dry weather, wet the earth under the beech mulch only to a depth of 8 mm.; under the fir mulch, 8.8 mm.; and under the moss, 4.3 mm. Besides this, the conditions vary according to the strength with which the water falls on the mulch. If the water, finely distributed, was sprayed on the moss cushion, 70 per cent. of the given moisture was soaked up, while of the same amount of water, supplied in the form of a fine running stream, only 14 per cent. was retained.

Forests.

The proximity of larger tracts of trees, viz., *forests,* must be considered as a means of saving the moisture in the soil of cultivated land. According

[1] Biedermann's Centralbl. 1880. p. 405.
[2] Forsch. auf. d. Geb. d. Agrikulturphysik, 1880, pp. 80-96.

to Matthieu's[1] observations, extending over 11 years, the air in forests, 1.5 m. above the soil, is on an average colder than above bare ground, the difference being the greatest in summer. The forests exert the same depressing influence on the mean air temperature as they do on the temperature extremes, which are less in forests. When the temperature differences amount perhaps to only 0.5°C., they are perceptible when a rain cloud passes over the region. Air will become saturated above the forest sooner than above uncovered land. Thereby the rain will begin sooner and be more abundant than on the land which is not forested. In fact measurements of Matthieu and Fautrat[2] prove greater amounts of rain above forests. Hygrometric determinations have shown that the weight of water vapor in one cubic meter of air above a spruce forest amounted, on an average, to 8.66 g., while above forests of deciduous trees it amounted to 8.46 g.; above uncovered soil at the same height (104 to 122 m. high), at a horizontal distance of 100 m. from the conifer forest, to 7.39 g.; at the same horizontal distance from the deciduous trees, to 8.04 g. Thus the proximity of the forest influences the moisture vertically and may also exert the same influence horizontally.

Fallow Land.

"Fallow Land" has less effect on the retention or increase of the water supply in the soil than on the accumulation of nutritive substances. According to Wollny's[3] statements, the peculiarities of fallow land may be summarized as follows:—Soil lying fallow is warmer in summer and colder in winter. Fluctuations of temperature are greater everywhere in fallow land than in soil overgrown with plants. During the time of growth the soil covered by plants has always a lesser water content than when lying fallow. This greater moisture content is retained in bare soil even when worked more frequently. Bare soil also gains more from atmospheric precipitation since, during the time of growth, considerably larger amounts of water percolate through soil lying fallow, than in fields provided with a growing plant covering. From the standpoint of nutrition the carbon dioxid content of fallow land is most noteworthy. Wollny's researches show that the air in fallow soil contains approximately 4 times as much carbon dioxid as in grass land. Therefore, the means for the solution of mineral elements in the soil are present much more abundantly; which explains in part the greater accumulation of nutritive substances in fallow land. This greater enrichment also depends partially on the quicker decomposition of the organic substances because of the greater temperature fluctuations, the increased moisture and the more vigorous activity of the micro-organisms. It should, however, be pointed out finally that soils with less power for holding water and in greater depths (sandy soils) with their greater permeability lose

[1] Matthieu, Météorologie comparée agricole et forestière. Paris 1878; cit. in Forschungen auf d. Geb. d. Agrikulturphysik 1879, pp. 422-429.

[2] Fautrat. Ueber den Einfluss der Wälder, den sie berührenden Regenfall und die Anziehung der Wasserdämpfe durch die Fichten. Aus Compt. rend. 1879, Vol. 89, No. 24; cit. Biedermann's Centralbl. f. Agrikulturchemie. 1880, p. 241.

[3] Wollny, Die Wirkung der Brache. Allgem. Hopfenzeitung 1879, Nos. 55, 56.

considerable part of the plant nutritive substances which are washed away into the subsoil. Such soils therefore, conversely, must be kept under a covering of plants.

Local conditions must show which one of these means can best be used to prevent a lack of moisture. In any case it is evident that we do not stand powerless in the face of drought.

b. Loamy Soils.

General Characteristics.

In considering physical influences injurious to vegetation, we need not distinguish between loam and clay soils. We are concerned always with mixtures of clay and sand and only the proportions of these two elements differ. The sand content decreases more and more from sandy or "mild" loam to *strictly loamy soil* and to clay soils, which are plastic in a damp condition; in them predominate the fine particles so easily washed away. In our agricultural land, mixtures of lime and humus will also be of importance as modifiers. Lime will make heavy soils more open by increasing their *friability*.

Fertility is directly dependent upon friability, hence plastic clays are sterile. Non-friable clay soils are impervious to water, and, in level places, easily give rise to the formation of swamps. The smaller the size of the soil particles, the greater will be their water absorptive power so that very significant changes in volume occur with extensive, rapidly successive differences in the supply of water. Upon this depends the characteristic *cracking of clayey soils* when drying out. Soluble salts can be washed out of clay soils only with difficulty.

This drying out is much more dangerous as the soil approaches pure clay. When once dry, clay takes water up again very slowly since it can penetrate only with difficulty between the closely packed soil particles. These peculiarities decrease proportionately as the admixture of sand increases. Drying out in summer becomes at times more dangerous in heavy soils than in sandy, especially if a vigorous growth of trees has developed in regions which at best are poor in precipitation. The summer rains do not then suffice to make good the loss of water. These soils are dependent on the *winter moisture*. Hence the plant growth suffers here much more in dry springs, in years when the winter moisture has been less and the snow covering has failed, than on sand. This explains the fact that, after hot, dry summers and winters, poor in precipitation, *a blighting of the tops* of old trees (i. e., a drying of the branches) sets in because of the lack of moisture, even if the spring has abundant rain. Sandy soils with moderate spring rains are saturated more quickly and the water is at the disposal of the roots.

Heavy soils remain "cold." This is explained by their high water content which increases with the fine granular structure. In many regions imported conifers (*Abies Pinsapo, Biota orientalis aurea, Taxus hibernica,*

Picea orientalis) die quickly. This is ascribed to winter frost but upon closer observation it is discovered that low temperatures become harmful only when the soil is very wet[1].

A deficiency of soil aëration is the most harmful factor since upon the aëration depend the phenomena of decay in the decomposition of organic masses. Thus in judging loamy soils as to their fertility not only the degree of friability, but also the depth to which this extends, becomes decisive. Since the firm loam layers of the subsoil are aërated only with difficulty, the spreading out of the root system takes place only in the friable layers. Therefore a special value should be laid on the maintenance of this friability. This must be taken especially into consideration in forests, where the *litter is constantly raked away*. Ramann's investigations[2] show that, in removing litter, the soil becomes densely packed and works harm to the forest tract.

The packing of soil and the necessity for loosening it should especially be considered in growing all *tropical plants,* as Vosseler[3] has proved. He describes the soils characterized by Koerts as "older red loam," and especially the primeval forest soil of East Usambara thus;—"The red soil consists mainly of fine loam and clay which is pervious but too finely porous to take up small humus particles; besides, chemical action takes place possibly in the upper surfaces alone and thus prevents their penetration into the lower soil. Since the soil itself is the final product of decomposition, it lacks the advantage of processes of loosening up which possibly take place during such action." Here also, therefore, the loosening of the soil is given as the first requirement for successful cultivation.

The more clayey the soil is, the more slowly the vegetable refuse will be decomposed because of the lower temperature. While in sufficiently friable soils, a normal decomposition takes place, masses of *raw humus* collect on thick clay soils, i. e., particles of plants, which are only slightly decomposable, remain deposited on the soil because the conditions are unfavorable for decomposition. If very fine grained soils with a greater *moisture holding capacity,* i. e., ability to retain large amounts of water without giving it off in the form of drops, acquire so much water that it overcomes the continuity of the substance particles by penetrating between them, thus forcing them apart, the soil becomes softer. This condition is especially peculiar to strong clay and red soil; such a *disintegration* occurs less frequently in loamy soil.

Such *reduction of the soil* is doubly dangerous, if it takes place in the autumn or spring. On the one hand, the soil washes away at once and the seeds are soon exposed to drying or to freezing as the case may be. On the

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1 Cordes, W., Beitrag zum Verhalten der Coniferen gegen Witterungseinflüsse. Hamburg 1897.

2 Ramann, E., Untersuchung streuberechter Böden. Sond. Z. f. Forst- u. Jagdwesen, XXX Jahrg; cit. Bot. Jahresb. 1900, II, p. 415.

3 Vosseler, Ueber einige Eigentümlichkeiten der Urwaldböden Ostusambaras, Mitteil. a. d. Biol. Landwirtsch. Institut Amani, 1904, No. 33.

other hand, this condition also *retards* working the soil and planting the fields, thus becoming a cause of poor harvests. Especial consideration should be given to the fact that, for all our cultivated plants, the usual planting time has been determined by observing the behavior of the plants in our climate. It can be shown at any time that variation in the periods of cultivation produces changes in the character of the plants (the change from winter to summer grain). Such a delay of the seeding time often acts injuriously, as, for example, in peas. The same seed that furnishes a fine crop of healthy plants, when sown early in spring, very often produces low plants with small pods, greatly injured by mildew, if sown in summer. Kohlrabi, planted too late in spring, easily become woody, etc.

Similar phenomena may be observed in fine sandy heath soils *(loose loam)*. Gräbner[1] characterizes this form of soil as consisting of sand grains almost as *fine as flour* with only small clay admixtures. The whole mass when wet looks like loam. In a dry condition, however, it may be distinguished from loam proper by its porosity. Thus, as a result of its very fine granular structure, it can become as hard as stone. In places which are cultivated constantly and kept loose by means of animal manure, such soil is often valuable but in forestry it is not, for, after the usual single loosening, the fine sand is at once packed together by rain and too little oxygen from the air can get to the roots of the trees.

The Covering of Soil with Silt.

In heavy rain storms and floods soils with a large content of very finely broken particles are washed together and, after the evaporation of the water, are left in the form of a thick, close *crust*. The moisture holding capacity of a soil increases with the fineness of its pulverization, as has been mentioned above. Increased pulverization of the particles deepens the upper surface and the power for retaining water depends on surface attraction. By pulverizing a soil mass, consisting of coarse pieces of quartz from 1 to 27 mm. in size, which had an absolute saturation capacity of 7 per cent., the capillary absorptive power was so increased that a fine sand produced from the quartz, the size of its grains being 0.3 mm., held back more than 6 times as much water. One sees that under certain circumstances the kind of mineral may be unimportant and only the mechanical constitution of value; that, therefore, even quartz dust can assume the *rôle* of clay. Naturally this dustlike sand has no coherance whatever, and can therefore never in itself take over the *rôle* of a binding substance such as clay. Principally, however, it is clay soils which suffer from erosion in the form of silt and, by making air tight layers, cause the decay of seeds and plant roots. At times the roots form accessory organs in order to find the necessary air in marshy soils. In this connection, attention should be called to the knee-like *outgrowths* of roots which struggle to the upper surface of the soil, as those

[1] Gräbner, Handbuch der Heidekultur, 1904, p. 200.

of *Taxodium distichum* and of *Pinus serotina* which are not formed on dry soils, and are described by Wilson[1] as aërating organs.

An example of the injury to vegetation, due to a direct *deposition of silt,* is furnished by Robinet[2] of Toulouse, where the nurseries had stood for only two days under water. At the base of some plants very little mud was deposited. These remained healthy. But when the mud covered the base of their trunks, possibly 10 to 12 cm. deep, the damage was great. Almond, acacia, cherry (even the mahaleb cherry) mountain ash, Ligustrum, Mahonia, Evonymous and most conifers were killed. Individual specimens of Crataegus, *Pirus Communis* (of which those grafted on the quince suffer less) *Pirus Malus,* Castanea, Mespilus, Catalpa, etc., which had stood 8 to 10 days under water, blackened at the base and died when the silt was not removed. Platanus. Alnus, Ulmus did not suffer, and Populus, as well as Salix (weeping willow), developed many roots from the base of the trunk out into the silt. All the specimens of Sophora, Fraxinus, Carpinus, Fagus, Betula and Robinia did not die; the *leaves* of the survivors, however, *turned yellow.* The linden and chestnut lost all their leaves. Evergreen plants, and even a part of the conifers, lost their leaves when they had been covered by water.

Of double importance is this change in the physical constitution of the soil in regions exposed to frequent inundations and, among them, the soils suffer most which are flooded by *sea water.* Aside from the injury to vegetation from the large salt content of the soil, there is found, according to A. Mayer[3], as a resulting phenomenon of a dense covering, noticeable at times only in the second year, a formation of a black layer, strongly impregnated with *iron sulfate,* which may further injure vegetation.

Von Gohren[4] also emphasizes the formation of such kinds of ferruginous layers called *"Knick"* in West Friesland in very humus, loamy and clayey mud deposits of sea and river marshes and explains their production by the fact that the ferric oxid in the loam is reduced to ferrous oxid by the organic substances in the absence of air. This ferrous oxid combines with the crenate acid to form crenic ferrous oxid. Crenic ferrous oxid, distributed in every direction, is gradually oxidized again, cements together all parts of the soil as ferric hydroxid and co-operates in the formation of *meadow ore* of such ill-repute. We will finish considering the formation of meadow ore when discussing the peculiarities of swamp soil and now turn first to the phenomena of silt covering under the influence of salt solutions found in the use of *fertilizing salts.*

Mayer's experiments show that particles of clay suspended in water are precipitated differently when they are in suspension in pure water or in water containing sodium chlorid and other admixtures. In pure water

[1] Wilson, W. P. The production of aërating organs on the roots of swamp and other plants; cit. Bot. Jahresber. 1889, I, p. 682.

[2] Revue horticole; cit. Wiener Obst- u. Gartenzeitung 1876, p. 37.

[3] Mayer, A., Ueber die Einwirkung von Salzlösungen auf die Absetzungsverhältnisse toniger Erden. (Forsch. auf dem Gebiete d. Agrik.- Physik. 1879, p. 251.)

[4] von Gohren; Boden und Atmosphäre. Leipzig 1877, p. 56.

the particles are deposited according to size (more exactly, according to the proportion of their surface to their mass). The finest particles remain uncommonly long in suspension since they are held by the attractive power of the water, which is almost comparable to a chemical solution. The attraction of gravity for these particles is powerless in opposition to this attraction. After the clay, which has been dissolved in a glass cylinder for the experiment, precipitates from a salt solution, it is noticeable that a layer consisting of close, fine clay particles has formed with a comparatively very clear fluid above it. Because of the presence of sodium chlorid, all fine clay particles are precipitated more as a whole (coagulated, according to Schlösing). *"Flocculency"* is thus produced. The fall of the somewhat coarser particles among these appears to have been held back, while that of finer ones has been somewhat hastened. It has been assumed that probably the presence of the salt has decreased the attraction between clay and water, since the water then lets the clay fall more completely. On the other hand the attraction of clay to clay must have been increased, and it is therefore more compact. Durham[2] explains the process by the fact that every bit of the attraction of the water otherwise required entirely for the suspension of the clay is satisfied by the salt of the solution. According to him, sulfuric acid acts like the solution of sodium chlorid, and, according to Mayer, all mineral acids behave in the same way. The same is true of mineral salts even in an excess of fixed alkali or ammonia.

According to the theories now prevailing, *electrolytes* act flocculently, i. e. all bodies which in an aqueous solution are partially split up into "Ions." Non-electrolytes have no action. At any rate, an electric current precipitates the flakes. It should therefore be assumed that the particles distributed in the water are charged with electricity and the cause of the oscillation may be sought in this electric charge[3].

The chief point, worth considering for all cultivated clay soils, lies in the fact that the nitrates, so far as deposition of the clay is concerned, approximate the chlorates and, on account of the ease with which they are washed away, rapidly cause the packing of the soil. By this is explained the mechanical destruction of soils rich in clay, when repeatedly *fertilized exclusively with nitrates.* At first fine crops are obtained but later retrogression takes place. *Sodium chloride fertilizing* used for certain plants has naturally the same destructive effect.

Behrens[4] calls attention to the real disadvantage of an excessive use of fertilizing salts. Their osmotic action comes especially under consideration. Because of this osmotic action of the soluble salts in the soil, it is more difficult to supply the water needed by the plant and the plant responds by a suitable modification of its organs. In correspondence with the physiological lack of moisture, the plant reduces its evaporation by forming fleshier

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1 Biedermann's Centralbl. 1883, Nov., p. 786.
2 Chem. News; cit. "Naturforscher" 1878. p. 112.
3 Ramann, E., Bodenkunde, 2nd. Ed., Berlin. J. Springer, 1905. p. 225.
4 Behrens, J., Ueber Düngungsversuche. Jahresb. d. Vertreter d. angewandten Botanik, II Jahrg. Berlin, Gebr. Bornträger, 1905, p. 28.

leaves with smaller intercellular spaces; this may be found in plants near salt springs and on the sea shore.

Among our cultivated plants, tobacco suffers most; it reacts exactly as in hot, dry summers and forms fleshier leaves with a reduced burning quality. Hunger[1] confers these observations, made in Europe, and says of the cultivation of the Dehli-tobacco on Sumatra, that the leaf most valued, most grown and most carefully selected, is large, thin, poor in oils, and develops only in the presence of abundant water as in continued rainy weather, while in dry weather small, thick, less valuable leaves, covered with many glandular hairs, are formed.

The Improvement of Soils Which Are Becoming Compact.

The improvement of the easily packed clay soils will have to lie in the increase of *their ability to be worked.* Heavy soils are unyielding, i. e., they offer great difficulty by sticking to the farm implements, when damp, and by hardness, when dry. Great clods are produced which generally do not fall apart easily if the clay or red clay soil is poor in humus. It is well-known that the best plan for working soil for spring planting is to break it up in the fall and let it lie in rough furrows. The freezing of the water in the interstices during the winter months reduces the tough clods to a mellow crumbling mass.

These advantages are available only for spring planting and disappear after the heavy rain storms of the summer. Therefore care must be taken to prevent caking by supplying humus or marshy earth; fertilizing with long strawy manure is very greatly used. However, *liming and marling* the soil have given very effective results. Practical experience has shown that the addition of calcium, which is in solution in the soil as the bi-carbonate, will hinder its caking.

A definite amount of all salts, even of the most effective, calcium and magnesium, must be kept in solution in excess of the amount necessary to start action if any deposition of the clay particles is to take place. Even in rivers the flocculent action of dissolved salts makes itself felt since, for example, the sediment in rivers flowing from lime regions is more quickly deposited than in those from regions poor in lime[2]. For agriculture, friability becomes directly important since *upon this depends the proper state of tillage.* The small bits of the soil behave similarly to the clay flakes. Hilgard proved the action of lime by tempering solid clay soils with 1 per cent. quicklime. While the original clay soil became as hard as stone after drying, that *mixed* with lime was found to be crumbly and mellow. Since, besides a continuous mechanical working of the soil, the salts also condition its looseness, this must be the case, to an equal extent, in forest soil also. If the soluble salts, determining the friable structure, are decreased, as by *excessive use of litter,* covering with raw humus, the leaching of the upper layers, etc., a packing of the soil must take place.

[1] Hunger, F. W. T., Untersuchungen und Betrachtungen über die Mosaikkrankheit der Tabakpflanze. Zeitschr. f. Pflanzenkrankh, 1905, Part V.

[2] Ramann loc. cit. p. 226.

A top dressing of waste lime from sugar factories is often made use of in the cultivation of beets. The mechanical effect makes itself felt not infrequently by the fact that, as a result of increased capacity for being heated and the scanty supply of water, these soils later cause ***heart rot and dry rot.***

Hilgard's statements[1] on the *"alkali soils"* of California are of great interest. The alkali places often found between excellent cultural lands contain so much salt that they become noticeable by efflorescence on the surface. Those which contain alkaline carbonates (and partially also borates) are distinguished by the difficulty or almost impossibility of producing a really friable soil. After each rain, a coffee brown, clay water, colored by dissolved humus, stands at times for weeks on those places, recognizable because of their lower position. The same working of the soil which gives good soil the consistency of loose ashes makes the alkaline land a mass of rounded clods varying in size from a pea to that of a billard ball.

After evaporation, heating and saturation with carbon dioxid, the blackish brown solution, leached from alkaline soil, gives 0.251 per cent. incombustible residue. Of this 0.158 per cent. was redissolved in water and this soluble part consisted of 52.74 per cent. sodium carbonate, 33.08 per cent. sodium chlorid, 13.26 per cent. sodium sulfate, 1.83 per cent. sodium triphosphate.

The 0.093 per cent. insoluble residue from the heated water extract contained 14.02 per cent. calcium carbonate, 5.37 per cent. calcium triphosphate, 5.77 per cent. magnesium triphosphate, 24.37 per cent. silica soluble in Na_2Co_3, 50.47 per cent. of ferric oxid, aluminium oxid and some clay.

In this case, as well as in many other alkaline soils in California, the addition of a sufficient amount of *gypsum* (land plaster) produces a striking effect. The caustic action of the alkaline carbonates on seeds and plants stopped at once so that where previously only *"alkali grass"* (Brizopyrum) and Chenopodiaceae grew, maize and wheat were produced without difficulty. The gypsum naturally requires a longer time for the mechanical change of the soil surface and its greater loosening.

INUNDATIONS.

In opposition to the frequently widespread anxiety when volumes of water break over cultivated land, it might be emphasized that, naturally, aside from the washing away of nutritive substances and the mechanical injury due to the pressure of the waves, vegetation is not extremely sensitive to a water cover over the soil for some time. Woody plants especially, as floods show, possess a great power of resistance, which continues as long as the water keeps moving.

Stagnant water, remaining for a long time on the surface of the soil, works the greater harm; for a shorter time, inundations in the form of

[1] Hilgard, Ueber die Flockung kleiner Teilchen und die physikalischen und technischen Beziehungen dieser Erscheinung. American Journal of Sciences and Arts. XVII, March 1879. Forsch. auf d. Gebiete d. Agrikulturphysik, 1879, p. 441.

dammed up water may come under the head of useful factors of cultivation. At any rate inundation will always be more dangerous than those methods of irrigation where the soil always remains accessible to the air. The oxygen content of irrigation water increases oxidation in the meadow soils since water filtering off through the soil shows a lesser amount of oxygen and, at the same time, an increased amount of carbon dioxid and sulfuric acid in comparison with water in use for irrigation[1]. So long as sufficient oxygen is present the slow phenomena of oxidation of organic substances into carbon dioxid, ammonia and nitric acid, which we term *decomposition,* are accomplished chiefly by the action of micro-organisms. If a scarcity of oxygen occurs, however, due to continued retention of the water, that process of decomposition begins, partly of a purely chemical nature, partly with the co-operation of bacteria, which we call decay, whose final products are compounds which may still be oxidized.

If the water accumulates in places where impervious layers of soil entirely prevent any vertical flowing away and all horizontal flowing away is also made difficult, the *land becomes marshy.*

With the excessive wetting of the soil, the symptoms are again seen, which usually appear gradually with *root decay.* In deciduous trees, especially fruit trees, and with grapes a premature *yellow leaf (chlorotic) condition* becomes noticeable, which advances from below upward. This advancing death and falling of the leaves from the base of the branch toward its tip bear witness to the fact that the growing branches strip off their older leaves in order to mature their younger ones, which happens also in a gradual drying up. By this means, yellow leaves may be distinguished from the *pale leaves* resulting from the action of frost, in which the young leaf apparatus is disturbed and its normal chlorophyll action retarded.

Conversion of Land Into Swamps.

R. Hartig's[2] observations show that stagnant water is most injurious in forest plantations since the sensitiveness of the trees to frost is increased and freezing and heaving occur in the seed beds. Hartig[3] observed *decay of the roots* to a devastating extent in the tracts of the young pines in Northern Germany. It begins between the 20th and 30th years when, after a short period of weak growth, the trees, still covered with perfectly green needles, topple over as soon as a weight of snow touches them or a high wind acts on them. It is found that the tap root (see Growth of Stilts, p. 92) is wet and rotted up to the base of the trunk while most of the lateral roots appear to be healthy. Such a decay of the roots may indeed be found in spruce plantations, but it is less noticeable because the superficially extended

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[1] Wollny, E., Die Zersetzung der organischen Stoffe und die Humusbildungen. Heidelberg 1897, Carl Winter, p. 351.

[2] Hartig, R., Lehrbuch der Pflanzenkrankheiten, 3rd. Ed. Berlin, Springer 1900, p. 263.

[3] Die Wurzelfäule, Zersetzungserscheinungen des Holzes, Berlin, Jul. Springer, 1878, p. 75.

root system makes the tree less dependent on the few roots growing down deep into the soil.

It may be observed, especially in the province of Brandenburg, that the healthy condition of pines ceases if the sand flats most suitable for this growth have depressions in the ground where the accumulated water forms marshy pools. Up to the edge of these marshy places the trees stand erect and are comparatively long needled. At the point where the black moor begins, the growth becomes weakened, the needles shorter and the tree shows very small annual rings which not infrequently cease entirely.

In the increased planting of the very profitable pine trees, carrying them even on to damp soils, it is not surprising that root decay is found there to a very marked extent. It is advisable to limit the culture of pines to sandy, open positions and to choose for heavy, wet soils, such species of trees as are found by experience to best endure moisture. In places where no definite agricultural system regulates the tracts, the suitable kinds of trees make a natural appearance in the course of years, because of their greater power of resistance in the struggle for existence. It is approximately the same as the gradual control of the position *in frost holes* by the kinds of trees which resist frost (hornbean, birch, aspen). The red alder can best endure the strain of *stagnant water*. Besides this, black and silver poplars, as well as most willows and the sweet birch, thrive on moist soils. The ash is often found also, but under these conditions the trunks are entirely covered with moss and canker-like swollen spots.

In order to overcome the injury due to turning land into swamps, its cause must be determined exactly. At times the condition is due only to a lack of air circulation, and here the partial clearing of the land of its tree vegetation by the removal of the undergrowth and the lower branches of the trees, together with proper thinning, would be beneficial. Even when the land only becomes slightly swampy, especially in mountains, it may be restored by planting with conifers (Spruces). This holds good for the cases when increased evaporation of the upper surface is sufficient to overcome the accumulations of water in the soil. As the trees grow, and because of their close proximity, their evaporating surface not only increases but also less and less water can fall to the soil, because of the thick shelter of leaves.

The very radical means of *removing the water by drainage or ditches* should be used in forest tracts only after careful consideration of all local conditions since this method is often attended by greater disadvantages than advantages. This is especially true in mountain forests where the lowering of the water level of one district may easily have wide spread effects on the surrounding region. In some cases, areas, especially slopes, with a strong tree growth, where there is no excess of water, become drier. Trees accustomed to the former amount of moisture deteriorate and may partially die. On plains such sharp changes due to drainage are less to be feared.

It would not be necessary to further discuss the formation of marshes if, aside from the exhalation of gases, injuries to cultivated land did not

follow attempts to drain the marshes and boggy places. The injury to meadows should be considered especially in this connection on account of the frequent use of injurious marsh and boggy water for irrigation. The conversion of irrigated meadows into marshes by overfilling the soil with sewage may be considered only in passing.

The statements of Bischof and Popoff[1] should be cited in connection with the exhalation of gases. The gases produced are often rich in hydrocarbons, especially methane or marsh gas (CH_4). Popoff investigated the gas developed in a cylinder which contained a slimey mass consisting of kitchen refuse and substances of similar character. This slime was kept 3½ weeks in the cylinder, at first at 17° C., later at 7 to 10°C., and gave gas mixtures of the following percentages of composition in the successive investigations which took place usually at intervals of 2 to 4 days:—

1.	11.75 CO_2	2.48 CH_4	4.71 O.	81.06 N.
2.	12.62 "	5.68 "	81.70	
3.	34.99 "	29.03 "	0.0 O.	35.98 N.
4.	55.81 "	42.54 "	0.0 "	1.65 "
5.	56.00 "	42.70 "	0.0 "	1.30 "
6.	45.9 "	54.1 "	0.0 "	0.0 "
7.	43.3 "	56.6 "	0.0 "	0.1 "

These figures show that at the beginning of the experiment part of the air found in the cylinder was driven out, and part used up, while the oxygen oxidized the organic fragments in the slime. So long as free oxygen was present, the formation of carbon dioxid exceeded that of marsh gas,—on the other hand, this proportion was reversed as soon as the oxygen was exhausted.

Proceeding with the hypothesis that it is the *cellulose in the slime* which is decomposed, assisted by the action of the lower organisms, Popoff put clean filter paper with a small quantity of slime into a flask. On investigating the gas formed after some little time, he found its composition to be 34.07 per cent. carbon dioxid, 37.12 per cent. marsh gas, 1.06 per cent. hydrogen and 27.75 per cent. nitrogen.

Near marshes, however, we also frequently detect the odor of *hydrogen sulfid*. This comes partly from the decay of protein bodies which form leucin, tyrosin and other substances by their decomposition and finally carbon dioxid, marsh gas, ammonia, etc. Erismann's[2] observations, cited by Detmer, make possible the determination of the quantitative composition of the gas given off in 24 hours from 18 cubic m. of excrement placed in a poorly ventilated cess pool.

The whole mass gave 11.144 kg. carbon dioxid, 2.040 kg. ammonia, 0.033 kg. hydrogen sulfid and 7.464 kg. marsh gas. In this decomposition oxygen and nitrogen were also set free. 13.85 kg. of oxygen are said to have been taken up by the 18 cubic m. in 24 hours.

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[1] Bischof's Lehrbuch der chemischen und physikalischen Geologie, 2nd. Ed. Popoff in Pflüger's Archiv f. Physiologie, Vol. X., p. 113.

[2] Zeitschr. f. Biologie, Vol. XI, pp. 233 ff.

Thus a comparatively very slight development of H_2S is found and it must be assumed therefore that, if large amounts of H_2S are formed in marshes and other places, they must owe their origin to a reduction of sulfates in the soil, conditioned by the organic substances present.

Pagel[1] and Oswald summarized the results of their investigations on such reduction processes in the substances of marshes and found that, in the absence of air, sulfur metals occur, as well as hydrogen sulfid, and that, together with this reduction of the sulfates, ammonia is set free from the marsh substances containing nitrogen. The authors do not state definitely whether these substances are produced only in the absence of air, but in their production may lie the harmful quality of *stagnant water.*

The Burning of Plants in Moist Soil.

In summers, remarkable because of great temperature extremes, it has been observed that on hot, clear windy days, plants of rapidly growing, large leaved crops, such as hops, wilt greatly, particularly when grown in damp places. The lower and middle leaves of plants growing in damp hollows are sometimes seen to turn yellow and brown at the edges and partially to dry up so that they can be rubbed to a powder in the hand. These specimens have been partly burned by the sun. The noticeable feature is that the burning takes place directly on those places in the field, in which, throughout the whole year, sufficient moisture is present, while in higher, drier portions, still more exposed to the wind, the plants usually suffer less. My comparative experiments[2] throw sufficient light on such cases. They prove that plants, which from the beginning produce their roots in a soil containing much water or even in water cultures, evaporate much more water per square centimetre than do plants of the same strain grown under conditions exactly similar except with a lesser water supply. It is an interesting but not very well-known phenomenon that many of our cultivated plants from very different families grown under optimum conditions, in producing one gram of mature, dry substances, evaporate approximately equal quantities of water,,—indeed the transpired water varies from 300 to 400 g. in amount. If the plants grow in localities which, like soils with an impervious subsoil, constantly have a great deal of water at their disposal, a constant nutrient solution will be present in the interstices of the soil, more or less highly concentrated according to the soluble materials present. If the concentration exceeds the amount favorable for the plant species, the plant grows less vigorously, remains short-limbed, small-leaved, but usually dark green. If the concentration is exactly right, the growth is very rich and luxuriant and the absolute water requirement is very great, but is small if reckoned per gram of dry material produced. Under such conditions the plant finds the soil water of great value. In excessively damp places, however, it often happens that the soil solution is poor in different nutritive substances.

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[1] Landwirtsch. Jahrb., Vol. VI, Supplement, p. 351.

[2] Sorauer, Studien über Verdunstung. Forschungen auf dem Gebiete der Agrikulturphysik, Vol. III, Parts 4 and 5, pp. 43 ff.

The weather requirement is greatest under such conditions just as if the plant made the greatest struggle to produce as much as possible from the very scarce nutrient substances present. The leaves, then formed, are very large and well spread, but are very little resistent to cold as well as to heat. They react unfavorably to influences which pass over other plants without leaving any ill effect.

Such disturbances occur earlier in plants in moist localities. On hot and especially windy days, evaporation is enormously increased, the amount of water transpired is then considerably greater than that supplied by the axial organs. Consequently the leaves on many plants wilt. The smaller the normal transpiration per square centimeter surface, the longer the amount of water brought by the stem, even on extremely hot days, will compensate for the loss of transpiration. The plants of damp localities which, as experimentally determined, evaporate much more water in the same unit of time than do plants from dry places, have thereby first of all reached the limit when lack of moisture in the cell acts injuriously. In these plants the leaves dry up first and not the very youngest nor the very oldest but, as a rule, those working most actively and in part still elongating..

Proper drainage to remove the water from those particular tracts of ground is the surest method of overcoming the trouble.

Delayed Seeding.

As a result of damp soil the time for planting is frequently delayed. The following are the results of experiments by Fr. Haberlandt[1] and H. Thiel[2]. The most detailed experiments were made by Haberlandt in 1876 with four kinds of summer grain in which, on the 1st and 15th of the months April, May and June, the seed was sown on a bed 3 sq. m. in size. The results may be summarized as follows: The amount of harvest in all summer grains decreased more and more as the seeding was delayed. This was based first of all on the considerably weaker growth of the grain planted late and was most evident in the smaller number of fertile stems. A decrease not only in the quantity, but also in the quality was very noticeable. The weight in straw increased with delayed sowing. In general the chaff and roots of the crop increased disproportionately to the weight of the grain. The quality of the grain itself also decreased greatly. Barley and oats from later sowings had a greater amount of chaff by weight; the smaller the individual grains were, the greater this disproportion became.

The later sowings were attacked to a greater extent by ergot, mildew, rust and especially by leaf lice. Besides this, up to the time of forming the blades, as well as blossoming and ripening, they required a greater amount of heat than did earlier sowings. Even the germinative power of the harvested grain was affected and of a lowered quality in seed from plants of

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[1] Haberlandt, Fr., Die Beziehungen zwischen dem Zeitpunkt der Aussaat und der Ernte beim Sommergetreide. Oesterr. landw. Wochenbl. 1876, No. 3; 1877, No. 2.

[2] Thiel, H., Ueber den Einfluss der Zeit der Aussaat auf die Entwicklung des Getreides. Ref. in Biederm. Centralbl. f. Agrikulturchemie. 1873, p. 47.

late sowings. In the first place, the percentage of germination was lower; in the second place, the grain from late sown and late harvested seed also required a longer time for germination. From Haberlandt's earlier investigations in this line, showing a lesser development of grain in bulk as well as in absolute and specific weight, it is further seen that the amount of soil moisture alone is not the only cause of the difference between late and early sowing. In these experiments the plants had a sufficient water supply, from the beginning, and yet showed these different proportions.

Thiel's experiments with late sowings were made at various times in the autumn. The time of harvesting for all the plants, even of widely different periods of sowing, was approximately the same, but very late sown seed had a very small yield so far as it remained alive at all. Indeed Thiel rightly calls attention here to the fact that late sown seed sprouted simultaneously with that sown earlier with corresponding spring weather, without, however, having had time to collect sufficient material for an abundant development as did the plants grown from seed sown earlier. Naturally the constitution of the seed plays a considerable *rôle* here. The older the seed, the more slowly the reserve substances are mobilized. With ripening and subsequent maturing, the amounts of sugar and amido nitrogen compounds decrease[1] and do not become prominent again until germination. The more or less favorable sprouting of the seed depends on its age and the soil constitution. At this point we will insert the warning that no reliance should be placed on the results of other *germinative tests*, but one's own soil must be tested directly as to its behavior with different seeds. Seed which keeps well, according to common germinating tests, may give poor results, especially in heavy soils and, conversely, a light soil may often help seed to make a good growth, which developed only a moderate quality in the germinating bed. Hiltner's[2] report, for example, on newly harvested rye, which had suffered from a thunder storm, showed that it grew well in some fields, but absolutely would not grow in heavy soil. In another case, rye, developing 97 per cent. seedlings in a germinating test, molded almost entirely on one field, while in an adjacent one it gave normal growth.

Souring of Seed.

In the section on too deep sowing (p. 106) we have already considered the disadvantages to which seed is often exposed in heavy or in incrusted soils with a large water content. Even germinated seed has to struggle against difficulties due to physical constitution of the soil; viz., from an excess of water in heavy soils. Here is found also souring of seed, which, to be sure, can occur also in light soils, but has been observed usually only in heavy, tough soils.

The souring is due to a decay of the roots which have been longer in contact with standing water, charged with organic substances. Most roots

[1] Johannsen, W., Studier over Planternes periodiske Livs yttringer, I; cit. Bot. Jahresb. 1897, I, p. 148.
[2] Hiltner, L., in Prakt. Blätter f. Pflanzenbau u. Pflanzenchutz, 1903, Part I.

withstand very well a continued contact with running or standing water, which is free from organic substances, as can be seen in the different water cultures. Here, however, all living or dead vegetable particles in the culture vessels are avoided, for the decomposing organic substances take up all the oxygen which is present in a small supply. The roots of the growing plant must be killed because of a scarcity of oxygen and excess of carbon dioxid. Also, under ordinary conditions, seeds can survive contact with water, lasting for weeks, if the temperature is low. Thus Feige[1] states that wheat which had stood for 5 weeks under cold water at 5°C. still lived. On the other hand, wheat kept 8 weeks under water, the temperature of which increased to 7°C. had disappeared without leaving a trace. Corn, which had previously been healthy, withstood water at 3°C. for 4 or 5 weeks, but was injured somewhat more than the wheat mentioned above. In the same way, alfalfa and clover withstood standing in water better than did corn.

According to Kühn, rye suffers especially from souring, while under the same conditions brome grass and others develop very luxuriantly. To this circumstance is due the erroneous belief, which even now occasionally appears, that rye can change into brome grass. According to our view, "Arrabbiaticcio" of wheat in Marengo and on the Roman Campagna belongs under this head. Peglion[2] explains the disease as a general deterioration of the plants due to being overrun by the luxuriant growth of weeds, which thrive better than the wheat on unsuitable soil. In Southern Italy the disease is called "calda fredda" and "secca molla."

The souring of the winter oil seeds, especially rape, is the most serious of all. From standing continually in water the roots decay from the tips backward so that in spring only the crown of the root and the leaf rosette remain. These appear to be healthy as long as the moist spring weather prevents their drying out, yet, as the season becomes dry, the plants turn brown very soon and may be drawn from the soil by one leaf.

An investigation by E. Freiberg and A. Mayer[3] serves to explain the fact that under continued wet conditions the character of the vegetation changes, so that phenomena appear like the above mentioned predominance of brome grass when rye had been sown. This experiment proved that the roots of marsh plants need much less oxygen than those of cultivated plants. This proves, as might have been supposed from the very beginning, that the individual plant species make different demands on the oxygen of the soil and, accordingly, must adjust their habitat to existing conditions. From the result of the experiments, however, another conclusion may be drawn which may serve in general when judging the demands made by different plants on soil; viz., the amount of air needed by their root systems. It is found that the more oxygen the plant needs for respiration, the greater is its nitrogen content. Marsh plants show a strikingly low nitrogen content and

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[1] From Oesterr. landw. Wochenbl. cit. in Biedermann's Centralbl. 1877, p. 76.

[2] Peglion, V., Sull' arrabbiaticcio e calda freddo. Annuar. d. R. Stazione di Patol. veget. Roma. Vol. I, 1901, p. 37.

[3] Freiberg, E, und Mayer, A., Ueber die Atmungsgröfse bei Sumpf- und Wasserpflanzen. Landwirtsch. Versuchsstationen 1879, p. 463.

have an open inner structure, permitting the storing of larger quantities of air within the body and suggesting the facilitation of internal respiration. Real water plants respire with a lesser intensity than land plants, as Böhm[1] found in his experiments, by measuring in a hydrogen atmosphere the carbon dioxid given off during internal combustion. Since it may be assumed that the amount of respiration is determined by the amount of protein burned in the plant's body, the oxygen needed by the root system will be greatest in cultivated plants, rich in nitrogen, and the most suitable soils will be those which most completely satisfy this need together with the other demands of the plant, i. e., rich field soil, which is loose or has been loosened.

Those lands, therefore, which are repeatedly subjected to an oxygen scarcity, through the formation of crusts from rain action and the deposition of silt by floods, will have to be improved by corresponding changes in their physical structure. In the cases of souring, on the other hand, in which the air supply is not necessarily cut off by the physical constitution of the soil and in which only an excessive supply of water can fill the large interstices in the soil, we will have to turn to the removal of the water.. Here deep drainage or at least drainage canals 120 cm. deep, lowering the ground water level by this amount, are the most advisable precautionary regulations. The development of so deep a pervious layer is necessary because many Leguminoseae, like alfalfa, and sainfoin, with their deep growing main roots and fewer fibrous roots, are apt to die when they reach the ground water.

Souring of Potted Plants.

The souring of *potted plants* occurs chiefly when loamy or peaty soils are used. If the drainage hole of the flower pot is stopped up and excessive amounts of water given by some inexperienced laborer, the roots of the potted plants die completely, since they become brown and soft.

The sour soil can be recognized at once by its characteristic odor. In this the process of decomposition of the abundantly present organic fragments, always contained in nutritive pot soils, takes place very differently. Probably acid compounds and also free acids are produced from the but imperfectly understood humus elements. If iron is present in the soil the uninjurious ferric salts can be reduced to the injurious ferrous ones, since, when the soil spaces are enlarged with water, a perceptible scarcity of oxygen must occur.

The water is saturated with carbon dioxid from the secretions of the roots and also from the decomposition of the organic matters in the soil, and, with continued action, the carbon dioxid is sufficient to kill the plants. W. Wolf[2] proved experimentally that healthy plants, set in water containing carbon dioxid, at once began to eliminate it in very greatly reduced quantities. The result is a wilting of the leaves which die later.

[1] Böhm, Ueber die Respiration von Wasserpflanzen, Sitzungsber d. Kais. Akad. d. Wiss. zu Wien. 1875, May Number.

[2] Tagebl. d. Naturf. Vers. zu Leipzig 1872, p. 209.

Even if we cannot yet explain with certainty the mechanics of wilting which take place here (the explanation given by W. Wolf[1] does not seem to be sufficient) we will, however, scarcely go astray in assuming that, as the result of the excessive accumulation of carbon dioxid in the soil water, the normal elimination by the roots of carbon dioxid, which is considerable in vigorously growing plants, is at once arrested. An unusually high *gas pressure* must therefore be produced within the plant, increasing to a *positive* pressure in the ducts and reducing their ability to conduct water to the aërial parts. The power of the ducts to conduct water will be decreased by the amount taken up by the negative pressure in the ducts. If thereby this conduction of water is weakened without corresponding reduction of the use of water in the leaves, wilting results immediately. If the plants are placed in distilled water, as in Wolf's experiments, a normal appearance and normal functions again set in. The distilled water in this case is like a sponge, absorbing the carbon dioxid and other excretory products of the roots.

Finally the result is the same for the root, whether the carbon dioxid appears dissolved in water, or as a gas resulting from an insufficient soil absorption. For the aërial parts of the plant, however, conditions are different and it is very important whether they come in contact with water rich in carbon dioxid or in air containing the gas. At least Böhm's experiments[2] on the leaves of green land plants have emphasized this. He immersed leaves of different land plants under water containing carbon dioxid and found that the plant no longer gave off oxygen if the part concerned was prevented from surrounding itself with an atmosphere containing carbon dioxid which would cut it off from direct contact with the water.

The results of excessive watering in pots with the drainage stopped and the consequent cessation of plant and soil activity are best determined by a microscopic comparison with the soil in a pot containing a healthy growing plant. What intense activity is found in the soil! From the upper surface down to the bottom of the pot (in leaf and heath earth) are found fragments of leaves and stems, on which many kinds of the so-called mold forms with sterile mycelia, or with mature conidia, exercise their power of decomposition. According to the nature of the vegetable matter, *Sepedonium (chrysospermum?)*, *Verticillium ruberrimum*, or *Penicillium glaucum*, Acremonium, Acrocylindrium, *Cladosporium penicillioides*, different kinds of Fusiarium and many others are found. On the upper surface often still other genera occur, especially the aërobic ones together with living diatoms and other forms of algae. The schizomycetes go deepest of all. Starch granules and bits of cytoplasm are found surrounded by colonies of rod bacteria radially arranged; colonies of bacteria have often been established also on fragments of crystals. All this active life is engaged in reducing the plant substance and favors the processes requiring oxygen, which we

1 Jahresber. f. Agrik.-Chemie, 1870-72, II, p. 134.
2 Anzeigen der Wien. Akad. d. Wiss., 1872, Nos. 24-25, p. 163.

term *decomposition.* All this active life will either be stopped, by closing the soil interstices with water, or be turned to those destructive *phenomena of decay,* decomposition in the absence of oxygen. Every soil has its mycological as well as its bacterial flora, which decomposes the organic substances. According to Oudemans and Koning[1], these are approximately typical for definite kinds of soil.

In potted plants it is safe to assume the beginning of stagnation when the upper surface of the soil is covered with a hard white or reddish colored lime crust, firmly attached to the edge of the pot. From the uncommonly large amount of carbon dioxid developed by the addition of acetic acid, it is evident that the *incrustation of the uppermost soil layers in the pot,* and at the edges, results especially from calcium carbonate.

Magnesium carbonate is met with and also ferrous carbonate, which later through oxidation, produces as ferric hydrate different colors in the crust. According to the microscopic examination, the characteristic swallow-tailed crystals of gypsum and the octahedrons of calcium oxalate, as well as the rhombic forms of calcium phosphate, soluble in acetic acid, occur. The presence of the last named salt can not always be demonstrated and never in large amounts. On the other hand, calcium carbonate and probably magnesium carbonate, together with very fine particles of quartz sand, make up the usual substances of the crusts, between which is perceptible at first an abundant fungous growth with a formation of conidia on the humus. The production of these crusts may be explained by the fact that the water, given in large quantities in watering, becomes charged with the carbon dioxid, abundantly produced by the process of decomposition within the soil interstices. Hence water is a splendid medium for dissolving the calcium carbonate present in the soil, the magnesia, the ferric phosphate, the ferric silicate, etc.

The more quickly the superfluous water is drawn away by good drainage in the pot, the less will the minerals be dissolved and washed away. On the other hand, if the water stands in the pot and once becomes charged with calcium, which is soluble in the form of calcium bi-carbonate, it can only be removed by evaporation from the saturated upper surface of the pot and, when the pores of the pot are not closed by a green, slimy algal growth, this excessive water also evaporates slowly through its sides; it leaves behind the dissolved substances. The pots *"become coated."* The calcium remains behind as calcium carbonate just as on the edge of a kettle in which water containing lime has been boiled.

Thus the usefulness of the two processes, the *frequent washing of the flower pots* and the *breaking up* of the upper surface of the soil, is demonstrated.

In the increasing desire to attain our ends by fertilization, different fertilizers are added to water soaked plants, but the main need,—sufficient

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1 Oudemans, C. A. J., et Koning, C. J., Prodrome d'une flore mycologique obtenue de la terre humeuse du Spanderswoud etc. Extr. Archiv. néerland.; cit. Z. f. Pflanzenkr. 1903, p. 60.

aëration of the soil,—is overlooked. The plants have not improved with this treatment. The best results are obtained by transplanting when growth starts and the application of heat to the roots to stimulate growth.

Eichhorn's[1] investigations prove that fertilizing may be injurious rather than advantageous with acid soil, in the presence of free humus acid. He states that earths, rich in humus, which contained free humus acid, liberate the acids from solutions of neutral salts. The acidification thus produced is stronger than it would be without these salts and, therefore, fertilization with neutral salts will increase the acid in such soils. This happens with calcium phosphate or any phosphate where the phosphoric acid, or calcium phosphate, passes over into solution. The addition of neutral potassium salts, especially alkaline sulfates, favors decomposition. If the humus acid is combined with a base, such acidification does not take place. The addition of manure, liquid manure, etc., will act only disadvantageously with such chemical decomposition and is to be avoided as are marly earths.

Injudicious Watering.

The frequent dying of house plants makes necessary a reference to injudicious watering. Excessive watering may be due to the fact that inexperienced people assume a lack of moisture in the soil as soon as the plant wilts. The fact that frequently, after watering, the plant becomes turgid during the course of the day gives weight to this assumption. If wilting follows this second turgidity, water is added until the plant is permanently wilted and the roots decay. Such conditions arise especially in the autumn when the more tender plants are put in conservatories with but little heat. The coldness of the soil then causes the wilting. We know from a number of cases cited by Sachs[2] that different plants require definite temperatures for their roots to keep them working, i. e., taking up water. Tobacco and pumpkins wilt in a soil at 3° to 5°C.; but if the same soil is warmed to 12° to 18°C., the root activity is re-established. In the examples cited above, when the previously watered, wilted plants become turgid during the day, this result is attributed to the influence of the watering. The real cause, however, was the diurnal rise in temperature of the air and of the soil, caused by the sun, whereby the roots were again stimulated to take up water. With the coming of night and the corresponding fall in temperature below the limit at which the roots are still to take up water, the wilting is repeated. The plant can therefore die of thirst even when the soil is very moist, if the soil be too cold. On the other hand, in moist air, the plants can remain alive a long time with wholly decayed roots, as is shown by water cultures. This is also the reason why, in root diseases, symptoms of disturbance are noticeable in the aërial organs only at a late stage.

Another cause of the wilting becomes noticeable in midsummer. If plants transpiring rapidly are exposed for some time to the hot sun and to

[1] Landwirtsch. Jahrbücher 1877, p. 957.
[2] Lehrbuch der Botanik, 1st. Ed., p. 559.

currents of air, they begin to wilt in spite of sufficient soil moisture, because the quantity of water evaporating through the leaves cannot be replaced quickly enough by the root. To be sure, the supply of water will be increased as the temperature rises simultaneously with the increased sunshine. According to De Vries[1], imbibition of the cell walls is increased and thereby their ability to conduct water, but the increased supply, nevertheless, cannot make good the loss through evaporation and the leaves must droop. If the pots are then watered, without having been tested, the earth will become sour.

The same result is found in the so-called New Holland and Cape plants belonging to the families of the Epacrideae, Ericaceae, Papilionaceae, Rutaceae, etc. The loose, fine, sandy, but little decomposed earth, such as heath mould, cannot be pressed very firm into the pots, because the undecomposed pieces of roots and leaves form a very loose consistency; with too heavy watering, however, the fine grains of sand and clay are first stirred up and then washed down so that only the long, loose fibrous elements remain at the upper surface of the pot. These naturally retain but very little water and let it run down very quickly to the bottom of the pot. On this account the upper surface of the pot is always almost half dry. If now the gardener lets himself be led astray and waters the pots under such conditions, and if the pots have no good drainage, the very fine roots will decay. (It should be remarked in passing, that the so-called soured pots quite frequently show an alkaline reaction. I found with potted plants, whose roots had decayed, that moist red litmus paper turned blue as far as it lay upon the surface of the pot).

As a means of overcoming this, transplanting into very sandy earth and sinking the soured plants in beds with warm soil has already been recommended. As a matter of course the roots must be cut back to the healthy part when transplanted. As a precautionary measure, the pots may be plunged into the ground and similar methods may be recommended. In doing this, however, a stick or a piece of wood, turned like a cone, should be used to make a deep, funnel-like hole, whose upper edge is exactly the size of the edge of the pot. The pot then hangs in the hole. Below the pot the lower part of the conical hole forms a cavity and prevents the earth worms from crawling into the drainage hole in the pot and stopping it up. In flower pots standing in a room, or on flower racks, the soil will not sour if only some little care is taken. The water content of the soil may be judged easily and comparatively accurately by tapping the pot. If the earth is full of moisture, the water lies between the individual particles of soil and the sides of the pot and the sound resembles that of a dense mass; when the amount of water is scanty, however, the pot rings hollow.

According to the above, therefore, one should consider not only how much to water, but in what way potted plants should be watered. In order to avoid washing away the finest particles of clay and sand and thereby

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[1] Bot. Zeitung. 1872, p. 781.

forming crusts, or choking the drainage of the pot, the water should ***never be poured quickly*** through the spout of the watering pot. In plants set in pots and sunken, a hose should be used, or, in pots set on forms in conservatories, a slender and long spout, giving only a gentle stream of water. One should avoid holding the stream of water at the base of the stem, which is often entirely white as a result of incrustations of lime.

Use of Saucers Under Pots.

In house plants the use of saucers under pots is general. This saucer is necessary for preserving cleanliness on the window sill and on the flower table, but is usually injurious for the plants themselves. No matter whether the pots be watered from above or by soaking up water from the saucers, the soil will almost always take up too much water. Many plant lovers consider this condition advantageous. The result, however, is a choking of the roots at the bottom of the flower pot. The decay of the roots continues gradually upward and finally shows itself in the dying of the edges of the leaves. If these symptoms appear, the plant is, as a rule, lost to the amateur, but the gardener can often cure it. For the amateur, who has no warm bed at his disposal, we would recommend setting the sick plant in pure sand and placing it in a warm, half shady place.

The Running out of Potatoes.

In discussing the disadvantages of heavy soils, we should consider the point of view, repeatedly brought forward in practical circles, that our potatoes "run out," i. e., gradually lose their good qualities and degenerate. Some people would explain this by holding that, in the customary method of propagation by planting tubers, one really propagates asexually, without interruption, an individual once produced from seed and that, thereby, an organism so long lived must at last show the weakened condition of old age. A proof of this is found in the retrogression in the starch content of our favorite older varieties as, for example, in the Daber potato.

According to our point of view, the cause of the supposed running out lies in the lack of foresight of the agriculturalist in growing varieties on heavy soil which have been produced on light soil.

We refer in this connection to Ehrenberg's work[1] on the results of 15 years experiments at the "Deutsche Kartoffelkulturstation." The average yield of all the varieties grown seemed to increase constantly from 1889 to 1903. In regard to the "Daber" potato, the yields decreased only on heavy soil which is easily explained since in Daber a very light, dry, sandy soil predominates. If newly grown seed of this variety was planted in heavy close soil, it gave better results than the form which had been cultivated there for some time. The same new seed, however, planted in sandy soil, usually gave a poorer result when compared with the naturalized plant. We find

[1] Ehrenberg, B., Der Abbau der Kartoffeln. Landw. Jahrb. Vol. XXXIII; cit. Centralbl. f. Agrikulturchemie, 1905, p. 235.

proof in these experiments that newly introduced seed retains at first the character developed in the place where it has been bred. If, for instance, heavy soil reduces the starch content, the reduction does not take place in the first year with new seed and therefore this seed contains more starch than the native seed. On sandy soil, however, a variety has been bred which contained the largest amount of starch possible under the conditions. The newly introduced varieties with the peculiarities brought with them, however, had not as yet adjusted themselves sufficiently to these conditions and therefore gave a lesser yield. Exhaustion or degeneration will therefore take place only where a variety does not find the cultural conditions it requires. The circumstances may be similar in all phenomena of supposed exhaustion or degeneration. *Our cultural varieties* are the products of breeding under very definite conditions of position, soil and weather, and are kept pure only if they again find conditions similar to those where they are grown. If it is desirable to make use of valuable peculiarities of any definite species in another locality, good results are obtained only by frequently renewing with seed from the native habitat or from habitats similarly situated.

Sensitiveness of the Sweet Cherry.

The complaint in different places that the sweet cherry every year suffers increasing injury from frost, the exudation of gum, attacks of fungi etc. is often due to the failure to observe the fact that the cherry does not like a heavy soil. This circumstance has been especially emphasized recently by Ewert[1] and deserves to be repeatedly borne in mind by the fruit breeder. Naturally here also some cultural varieties are able to adapt themselves better to heavier soils, but in general the rule holds good that the sweet cherry likes a light, deep soil and flourishes especially well on alluvial sand and loose soils. The amount of nutrition in the soil is a far less decisive factor than its physical constitution, especially its granular condition.

Often a scarcity of lime is given as the cause of poor growth, which can be overcome by supplying lime. The improvement in growth, however, may not always be traced back to the nutritive action of the lime but to the change in the physical soil condition due to it, viz., greater friability and thereby increased aëration. Ewert's statements throw light on lime as a nutritive substance. He states that the sweet cherry flourishes even when the lime content is from 0.04 to 0.15 per cent. Soil with possibly 80 per cent. of easily washed away particles is not suited to the growth of cherries even with 40 to 45 per cent. $CaCO_3$, if this is chiefly present in so fine a condition that it also can be washed away. The cherry is peculiarly sensitive to standing water and it grows best in dry soil in open places.

The Tan Disease.

Trees standing on damp ground may show decreased growth, especially if their early growth was rapid. The older bark cracks or, after the outer-

[1] Ewert, Das Gedeihen der Süfskirschen auf einigen in Oberschlesien häufigen Bodenarten. Landw. Jahrb. 1902, Vol. XXXI, p. 129.

most cork layers have fallen off, blister-like or flat, warty swellings put in an appearance and later these have a diseased wooly outer surface. If the place becomes somewhat dry, a reddish yellow to a brownish yellow powder may be brushed off which in color resembles fresh tan bark. This may have given rise to the term "Tan Disease." In introducing the subject of this disease into scientific discussion I have retained the name used by practical growers.

Fig. 23. Apple root with ruptured tan spots, natural size. (Orig.)

The same process takes place also in roots and young branches. Young branches with knotty tan pustules may be found in cherries. Up to the present this disease of the bark of the older trunk and roots has been observed most frequently in apples. Plums seldom suffer. Similar processes, resulting in the falling off of larger pieces of bark, have been found in elms and will be treated under growth disturbance due to marshy soils.

In figure 23 is seen a piece from an apple root, natural size. Its bark has been broken open by cross-tears varying in size, the edges of which have been forced back; the open places are covered with an ochre powder or (when first taken from the soil) with soft, moist, brown masses. Figure 24 represents a cross-section through such a callus place. We find the wood (*c* is the cambial zone) of a practically normal structure traversed by the medullary rays (*m*), most of which show no variation whatever. Only in some (*m'*) it is noticeable that in the younger portions they begin to broaden, thereby causing a looser construction. This process of loosening, however, finds its evident expression only in the bark where the rows of medullary ray cells, beginning to separate from one another, form loops. While the younger inner bark, with its hard bast cords, still shows no change from a normal structure, the older layers (at left side of the illustration) display an impoverishment of the cell contents and some radial stretching (*k'*). This excessive elongation of the bark parenchyma becomes greater, the further toward the outside the cells lie, and it increases within the cork zone in such a way that the cells lying free on the outer surface take on a pouch-like form (*s*) and are only very loosely united with one another.

If the outer surface of the root dries off, the cell pouches shrink and, in the outer layers, are entirely separated from one another. Then a tan-colored, powdery mass forms which may be wiped away with the finger. Even the lamellae of plate cork (t) which are present at the edge in thick layers (of equal size, under normal conditions) and, gradually dying back from the outside, fall away at the place of the tan disease, are also drawn into the process of loosening. These split off because some of the middle layers round off their cells and show a tendency to assume the structure of cork as will be described more fully later under the cherry.

Fig. 24. Cross-section through a diseased spot in an apple root. (Tan disease.) (Orig.)

If the outgrowth of the bark at the edge of the tan canker and the emptying of the cell have reached maturity, the well-known hourglass arrangement of plate cork layers occurs (t') which cut off the hypertrophied bark parenchyma, finally becoming cork, and it becomes an element of the bark scales. The cell elongation meantime advances laterally and further toward the inside. Thus at w we see the beginnings of this since the bark cells, normally elongated tangentially, are becoming square in cross-section and increase in number by division in order to round off more toward the diseased side, to become more open by enlargement of the intercellular spaces (r) and finally to pass over into the radial elongation which increases to pouch-

like outgrowths. By this advance of the process of over-elongation into constantly younger bark parenchyma layers, the activity of the root is finally exhausted at the place of the tan disease.

The injury is not so intensive in the aërial axes Sometimes in larger trunks the phenomenon is not noticed until the bark is closely examined. It is then found that some bark scales stand out raggedly. If these are removed, which may be done very easily, it is observed that the outermost layers of the succulent bark tissue form irregular blister-like swellings which rupture later and decompose into dust-like masses which may be wiped away in dry weather. Figure 25 shows the fresh bark surface of an apple tree which has been laid bare by the removal of the outer bark scales.

Fig. 25. Piece of the bark from the trunk of an apple tree with the tan disease.

a the calluses of the tan disease, *b* fragments of the dry bark scales covering the whole (Orig)

On this greenish brown, juicy surface hemispherical or elongated warty excrescences (*a*) appear very clearly. Figure 26 shows a cross-section through such a boil-like swelling in which, however, the wood, cambium and youngest inner bark have not been drawn. We recognize at the first glance the correspondence in structure with that of the tan spot of the root. At the lower part of the figure we find the bark parenchyma with three hard bast bundles of a normal arrangement and position, but close above these hard bast bundles is noticeable a change in position since the tangentially elongated bark cells, rich in chlorophyll, begin to increase in length radially (*r*), to divide and to be arranged in parallel lines broken by large intercellular spaces (*i*). The fact that this change in tissue must have taken place very early, at the time of pushing out from the cambium, is evident because the permanent tissue of the collenchyma (*cl*) has developed only one layer within the tissue of the excrescence. The chief part of the swelling has come from the peripheral layers which have developed into cushions (*w*) of elongated, finally pouched cells (*s*), which have raised the plate-cork cell layers and finally split them.

In explaining this phenomenon we must not forget that these tan places arise underneath the old bark scales, and, with a formation of full cork, finally become bark scales by suberization. Thus we find that the organization of the bark into constricted and constricting cell layers, as they alternate in the bark, has taken place in the young bark tissue, for we find that, in young fresh bark tissue, cross bands of plate-like cells, varying in structure and the

constitution of their walls, transverse in curves (*np*) the hypertrophied tissue, which, at the beginning, contains starch.

This formal and functional organization of the bark parenchyma which determines the formation of the bark may be found also in other tree barks, but first occurs, so far as I have observed, in the older axes in which the bark parenchyma has been influenced by the pressure of the bark scales lying above it. On this account I have called these bands of tangential cells

Fig. 26. Spot on the trunk of an apple tree with the tan disease. Explanation of the letters in the text. (Orig.)

(*np*) *"Pressure bands,"* which later suberize, often also developing plate cork cells and cutting off the bark scales.

I have had opportunity to study the tan disease in young cherry branches in a wet summer on very vigorous young trees in a nursery. Figure 27 shows that on these cherry branches the outer bark had split or been torn open in broad, irregular stripes (*e*). An intense yellow ochre colored mass (*f*) could be recognized at the ruptured spot, which, when tapped vigorously, gave off a powdery dust. The whole impression given by these branches was as if they had been very thickly covered with rust fungus.

The first indication of the disease occurred in July, when, among normally growing trunks, the leaves of some specimens turned yellow and fell off. Nevertheless the terminal buds of the branches developed a vigorous August growth which held most of its foliage until fall. In September the outer bark covering split and the surface appeared like yellow ochre velvet beginning at the lowest part of the branch and decreasing in intensity toward the tip. Further, the fact is worthy of notice that practically only the luxuriantly growing wild trees appeared to be diseased. The phenomena of the tan were only sparsely noticeable in grafted trees. It was seen at once that branches, where they had retained their leaves, had only a few really torn spots in the bark, indeed only closed, warty excrescences, i. e. the younger stages of the disease. In the axils of two year and much older diseased trees, ruptured places in the bark (*r*) occurred less frequently. Usually the individual centres of disease appeared there in the form of very broad, very high yellow ochre cushions running crosswise.

Fig 27. One year old and two year old cherry branches with tan cushions between the split bark stripes. (Orig)

The investigation of these cushions and of the broad, ruptured, discolored surfaces on branches one year old showed at once marked correspondence with those on the older ones; only it could not be seen that the lenticel cushions give off any dust. The discolored masses were found to be light brown, cylindrical, wrinkled cork cells with rounded corners, which were broken off individually or in small groups.

The branches, giving off this dust, seem with a few exceptions to be otherwise healthy, only their primary bark is very much broken by the considerable separation of the parenchyma cells. Places with loosened structure are found in the wood as well as in the bark. Cross bands of ductless parenchyma wood may be noticed in the stages produced toward the

middle of summer. These are filled full of starch, while the normally constructed wood, excepting the medullary rays, has none. Within these cross bands the medullary rays are broadened and have gummy spots.

The beginnings of the tan formation are found close under the terminal buds of the topmost branches, where the epidermis is still uninjured, but is already underlaid with cork, possibly five layers thick. In places, this protective layer, consisting of comparatively thick walled cells, corresponding to plate-cork, shows a change even in its first stages, so that the cells lying directly beneath the epidermis have developed into parallel rows of cylindrical, radially elongated, brown-walled, full-cork cells. There is present here, therefore, the character of lenticel growth which Stahl[1] has already described thoroughly for the cherry and which only differs from his description in that here the full cork cushions are rarely produced under the stomata.

It is seen that an extensive formation of full cork can take place independently of the stomata in the development of a plate-cork layer, since several layers of lenticels are produced in which the cork formation advances inward into the primary and, in fact, into the secondary bark.

As the shoot of the current year becomes older, a second layer of plate-cork appears very normally, directly beneath the one first produced. It has been found just as thick (viz., 5 to 7 cells) as the first whose cells gradually collapse with the apparently lessened swelling and the browning of the walls. During this process the normal cork covering of the cherry trunk appears to be differentiated into two layers. The upper, older one is very dense, since the cells usually have so collapsed that their cavities are recognizable only as fine lines; this layer passes over gradually into the second, later formed cork layer. In the latter, the plate-like cells are very uniform and their wide lumina are filled with a watery content or even with air. They border on a browned cell layer, with a clearly protoplasmic wall lining, which, as cork cambium, assumes the continued formation of the cork layer occurring in places. When treated with sulfuric acid, the composition of the oldest, sunken, collapsed brown cork layer is easily recognizable, since the cells are often distended and show in places their original height and width, at times almost square in cross-section, while the full cork cells are not changed. With this treatment the layer, produced later, rounds out its youngest cork cells into hemispheres after the cork cambium has been destroyed.

In the formation of the many layers of lenticels, the development of such elements is repeated in the secondary cork layer underneath the first centres of full cork.

The second case of lenticel formation, not connected with stomata, is illustrated in figure 28. This shows the cross-section of a new structure on

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[1] Stahl, Entwicklungsgeschichte und Anatomie der Lenticelle. Bot. Z. 1873, No. 36.

the barked cherry trunk. We must imagine that all the tissue here shown in the form of a callus covered with bark rests upon the old wood cylinder from which the bark has been removed.

Since reference to the anatomical processes, leading to the formation of this new tissue on the exposed wood, is made in the chapter "Wounds" (bark wounds), we will mention here only the fact that, if at any given time the bark is removed from a tree, the newest cambium, thus exposed, begins to grow again and covers the wounded surface with a parenchymatous tissue layer. This parenchymatous covering is increased by the later appearance of a constant meristematic layer. The inner surface of this layer forms

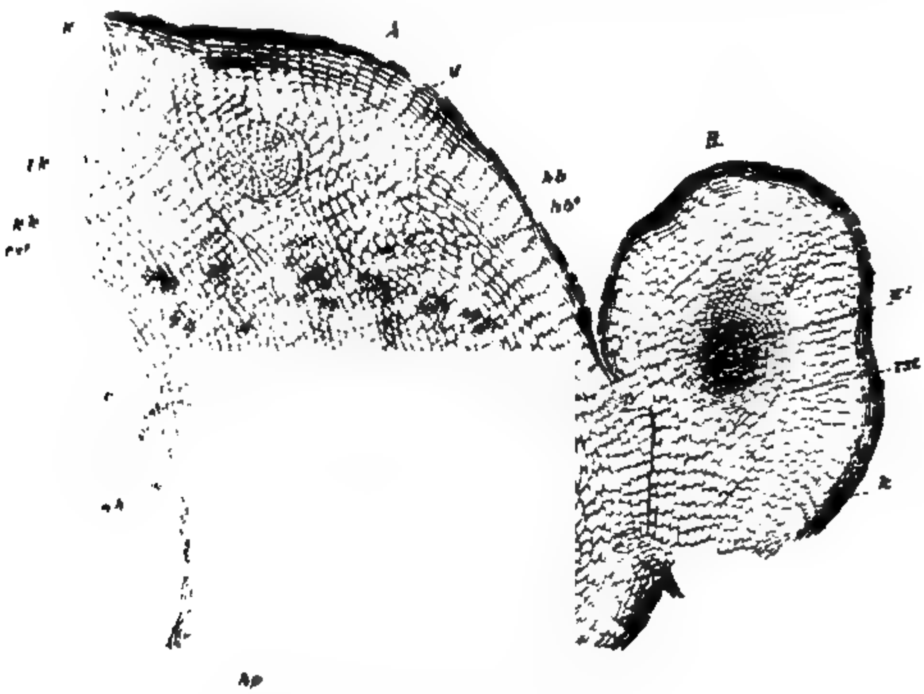

Fig. 48. Newly formed wood and bark body on the bark wound of a cherry trunk. The bark shows a lenticel excrescence. (Orig.)

normal cambium, which gives rise to woody tissues toward the centre and bark towards the periphery.

Figure 48 is a new structure several months old which, in the form of a broad wrinkled callus, has grown on the cambium of an experimentally barked sweet cherry trunk. The old wood of the barked trunk has been omitted in the drawing; it would join on at *hp*. The cambial zone (*c*) has sharply differentiated the tissue into wood and bark. The wood, where it rests on the old trunk, has a parenchymatous structure (*hp*); which later passes over into a vascular new wood (*nh*) forming libriform fibres. The structure of the bark is at first irregular and corresponds to the formation of wood which only gradually obtains its normal structure, for the hard

bast bodies began in the form of [illegible] was [illegible] and only later grew out from the cambium as [illegible] groups of elements (B) elongated like fibres.

The bark of the new structure has formed a [illegible] cork layer in its peripheral parenchymatous layers which has gradually grown very thick. At first only plate cork was formed; but later, in different places, full cork masses (*lk*) developed instead of the plate cork cells, splitting the covering (*k*) composed of the latter cells and pressing the cork cambium inward (*kk*) by their increase which extends further and further backward.

The full cork began to form when the whole peeled surface, for the purpose of further investigation, was enclosed in a glass cylinder, partly filled with water. While this lenticel out growth, produced from the phellogen, was only slightly noticeable in those parts of the bark which remained in the air, it had developed an unusual luxuriance below the surface of the water.

The tan disease of the cherry is therefore an abnormal increase of the normal lenticel formation. So many and such extensive full cork cushions are produced close to one another that they unite, pushing off the epidermis in large connected tatters and appearing as uniform velvety surfaces covering a large part of the branch. The outermost layers of the full cork cushions are so loose that the connection between the peripheral cells is broken by a slight blow when the air is dry; this explains the discoloration and the dust flying from places affected with the tan disease, if the spots be touched or shaken vigorously. This scattering of the dust increases with the number of full cork cells lying above one another and cushions composed of parallel rows of full cork, 20 cells deep, have been observed. In this case the process of elongation has included the entire thickness of the primary phelloderm so that the later formed, secondary full cork lies directly underneath this, i. e., no separating plate cork layer is left between the different generations.

The appearance of the tan disease will have to be traced to the *superabundance of water in the bark body*. This local excess of water may be due, on the one hand, to supplying the roots abundantly with water, especially

Reference should be made in passing to the illustration of the beginnings of tuber gnarls not in any way whatever connected with [illegible] in the drawing at B. They are produced by [illegible] for example, the [illegible] wounds of various trees [illegible] formation with [illegible] bast cells [illegible] The case in which [illegible] is of very frequent [illegible]

the barked cherry trunk. We must imagine that all the tissue here shown in the form of a callus covered with bark rests upon the old wood cylinder from which the bark has been removed.

Since reference to the anatomical processes, leading to the formation of this new tissue on the exposed wood, is made in the chapter "Wounds" (bark wounds), we will mention here only the fact that, if at any given time the bark is removed from a tree, the newest cambium, thus exposed, begins to grow again and covers the wounded surface with a parenchymatous tissue layer. This parenchymatous covering is increased by the later appearance of a constant meristematic layer. The inner surface of this layer forms

Fig. 28. Newly formed wood and bark body on the bark wound of a cherry trunk. The bark shows a lenticel excrescence. (Orig.)

normal cambium, which gives rise to woody tissues toward the centre and back towards the periphery.

Figure 28 is a new structure several months old which, in the form of a broad wrinkled callus, has grown on the cambium of an experimentally barked sweet cherry trunk. The old wood of the barked trunk has been omitted in the drawing; it would join on at *hp*. The cambial zone (*c*) has sharply differentiated this tissue into wood and bark. The wood, where it rests on the old trunk, has a parenchymatous structure (*hp*); which later passes over into a vascular new wood (*nh*) forming libriform fibres. The structure of the bark is at first irregular and corresponds to the formation of wood which only gradually obtains its normal structure, for the hard

bast bodies begin in the form of individual, short elements (*hb*) with wide lumina and only later grow out from the cambium as connected groups of elements (*hb*[1]) elongated like fibres[1].

The bark of the new structure has formed a protective cork layer in its peripheral parenchymatous layers which has gradually grown very thick. At first only plate cork was formed; but later, in different places, full-cork masses (*lk*) developed instead of the plate cork cells, splitting the covering (*k*) composed of the latter cells and pressing the cork cambium inward (*kk*) by their increase which extends further and further backward.

The full cork began to form when the whole peeled surface, for the purpose of further investigation, was enclosed in a glass cylinder, partly filled with water. While this lenticel out-growth, produced from the phellogen, was only slightly noticeable in those parts of the bark which remained in the air, it had developed an unusual luxuriance below the surface of the water.

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The appearance of the tan disease will have to be traced to the *superabundance of water in the bark body.* This local excess of water may be due, on the one hand, to supplying the roots abundantly with water, especially

[1] Reference should be made in passing to the illustration of the **beginnings of tuber gnarls** not in any way whatever connected with the tan disease but shown in the drawing at B. They are produced by a local accumulation of plastic material as, for example, the isolated wood in the bark of the new structures formed near the wounds of various trees (cherry, apple, pear and pine). At the centre of such wood formations with a spherical wart-like structure may be recognized one or more hard bast cells.

The case in which hard bast cells (especially diseased ones) are overgrown by tissue is of very frequent occurrence in injuries of very different origin. This overgrowth consists usually only of a covering of plate-like cork cells several layers thick. In some cases, however, instead of the rapidly transformed cork cambium, a persistently active cambial layer is formed which deposits wood elements toward the inside and bark elements toward the outside. Such a case is represented in the wart-like tissue excrescence (B) at (u') while at (u) in the left part of the figure (A) may be seen only a cork covering around one of the isolated hard bast cells first produced. The bark rays pass around these new structures on both sides as if around some foreign body.

The roots decided the matter. They had a rough appearance due to a great many black, hard cushions, differing in size and flattened into hemispheres, which covered the upper surface. If treated with a solution of caustic potash, when the tannin, occurring as a flocculent precipitate, turned a *wine red to brown,* cross-sections show that the bark excrescences were covered by a normal cork layer. The primary bark had developed parenchymatous excrescences the cells of which, arranged in radiating rows, had colorless walls, apparently dissolving with difficulty in sulfuric acid, and had a very firm brown content. These bark excrescences were later cut off by an hourglass-like, plate cork lamella, distending the outer cork layer, and were forced out over the upper surface of the root as calluses by the subsequent growth of the inner bark. The healthy bark was filled with starch.

In the material sent me the branches had only very slightly raised bark excresences, possibly ¼ to ½ mm. broad, flattened and hemispherical. In them was found the beginning of a many layered lenticel excrescence such as had been observed in great numbers in the cherry with the tan disease. The constitution of the leaves, still remaining on the branches, had already indicated the diseased condition of the roots. They showed a browning and drying up of the parenchyma in the intercostal fields, extending from the edge toward the mid-rib. Finally, the parenchyma was green only in the immediate proximity of the ribs. The black, yellow-edged, roundish spots, scattered over the sick leaves and containing various fungi colonies, must be considered as secondary phenomena. The condition found in the branches in connection with the excrescences on the roots brings the disease, which has been termed "Mal nero," into the group of the tan diseases. Accordingly, the choice of fibrous or good friable land which has a constant, abundant soil ventilation will be the best precaution against the disease.

The Rootblight of Sugar and Fodder Beets.

As rootblight we designate a disease of the tissues which can set in even when the young seedlings unfold their cotyledons or begin to open the first leaflets. A black spot appears on the stem below the seed leaves which spreads further toward the root end (less toward the cotyledons) and becomes depressed. Even if the young seedling has not reached the upper surace of the soil, the first stages of the disease can be recognized. Vañha observed that the tissue becomes glassy before turning brown. The little plants begin to wilt and usually break at the diseased point. Death results at once. If the disease is limited to a small area on the hypocotyledon stem and the plant does not succumb, the depressed place will heal and a normal, later growth follows. Because the diseased place blackens and often shrinks to the size of a thread below the seed leaves the practical grower also calls the appearance *"black leg"* or the *"threads."* The same term is used as well in the blackening and softening of the hypocotyledons of cabbage plants, which arise, however, from other conditions.

It is noteworthy that often great numbers of beet seedlings are diseased, and yet frequently perfectly healthy plants may be formed close to the diseased ones. It should be emphasized further that, when the disease develops at all it is found simultaneously in all parts of the field, and that, as a rule, isolated spots are not attacked in the middle of diseased fields. As the plants become older, the rootblight ceases. The healed plants usually, however, remain below the healthy ones in size and sugar content and show a tendency toward root splitting and other deformities. Stoklasa[1] emphasizes the fact that all varieties are not equally susceptible to rootblight.

The disease has been known since the increase in beet culture in the 30's of the last century and, according to Stift[2], the discussion as to the cause of the phenomenon began in 1858 at the meeting of the beet sugar manufacturers of the Zollverein. At that time the opinion was expressed by practical growers that the trouble was due to the physical condition of the soil, i. e., a too great *solidity of the soil.* It was emphasized that rootblight was found only where the upper surface of the soil was hard and had not been loosened on which account a thorough cultivation and stirring were advisable.

At the time scientists took up the question, the parasitic theory was already at the crest of its development. At first Julius Kühn in 1859 gave expression to the opinion that the moss button beetle (*Atomaria linearis* Stephn.) attacked the plants, and, where it had eaten, the rootblight made its appearance. I have observed something similar[3]. The centipede and such animals were also cited as causes. This theory which prevailed for many years was first upset when Hellriegel found that the disease could be produced without animal injury and in many cases came from the beet-seed. As a result he advised a soaking of the beet-seed for 20 hours in a one per cent. carbolic acid solution[4]. Karlson, at about the same time, ascribed the phenomenon to a special fungus and in this emphasized the fact that only weak specimens succumbed to rootblight. Seedlings from very good seed or those which were strengthened by an energetic growth, would not be overcome by the fungus carried in these seed balls (Scleranthus)[5]. The experiments in sterilizing with carbolic acid and with copper sulfate showed a decrease of the rootblight. In spite of the advantage due to sterilization, Karlson lays especial stress on the selection of especially strong seedlings and lays the responsibility for the spread of rootblight on our present cultural methods[6], which aim only at obtaining large amounts of seed and neglect the quality.

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[1] Stoklasa, Jul., Wurzelbrand der Zuckerrübe. Centralbl. f. Bakteriologie. Section II, 1898, p. 687.

[2] Stift, Anton, Die Krankheiten der Zuckerrübe. Wien 1900. Verlag des Centralver. f. Rübenzuckerindustrie.

[3] Zeitschr. f. Pflanzenkr., 1892, p. 278.

[4] Hellriegel, Ueber die Schädigung junger Rüben durch Wurzelbrand etc. Deutsche Zuckerindustrie, Jahrg. XV, p. 745. Biedermann's Centralbl. 1890. p. 647.

[5] Hollrung also found a lesser degree of disease in sowing large beet seed balls (Scleranthus). Dritt. Jahresb. d. Versuchsstat. f. Nematodenvertilgung. 1892.

[6] Blätter für Zuckerrübenbau, 1900, No. 17.

The theory of seed sterilization was further developed by Wimmer, one of Hellriegel's collaborators. Of the different substances used in sterilizing, carbolic acid was proved to be the most advantageous and, in fact, when used in the one per cent. solution of "Acidum carbolicum crudum 100 per cent. Pharm. Germ. II." To one part by weight of seed should be reckoned about 6 to 8 parts by weight of liquid. A warm water solution was proved favorable as well as a cold water solution[1].

While Wimmer left the question undecided as to the influence of the weather and the soil constitution Holdefleiss held to the theory that this and not parasitism caused rootblight. In soils favorable to the disease, he usually found an abundant amount of ferrous oxid, but comparatively little calcium. In this the *tendency to choking with mud and incrustation of the soil* are unmistakable and the discovery that rootblight was cured by abundant hoeing was in accordance with this. On this account Holdefleiss recommends, in addition to a continued, open condition of beet soils, a rich addition of burned (quick) lime (12 to 15 centner German per acre)[2] which is given with the best results to the first grown crops and not directly to the beet. Loges[3] had good results from the addition of 7 cent. of quick-lime per acre. As a further contributory factor, Hollrung emphasizes a lower temperature and the fact that rootblight never extends above the surface of the soil to the aërial parts of the axis which are exposed to air currents. He asserts definitely that rootblight is brought about by physical and chemical causes making themselves felt in cold soil, impermeable to air currents. The theory that the soils, in which black leg of the beet occurs, are easily choked with mud and become hard is substantiated by Marek and Krawczynski. According to Stift's statement (loc. cit. 10 to 20) in such a soil 77.25 per cent. fine sand was found.

Opposed to these theories, shared by many other investigators, the parasitic theory was still maintained and found its most active defender in Frank. Frank, with Krüger, from 1892 on, made various experiments and determined that, besides the *Pythium de Baryanum* found by Lohde, and occurring in many diseases of seedling plants from very different genera, besides the *Rhizoctonia violacea* mentioned by Eidam, there was a specific beet fungus, *Phoma Betae* Frank, "which not only causes heart and dry rot of the mature beet, but also the rootblight of the young beet roots."[4] Repeated discoveries in field experiments, however, soon showed even this investigator that weather and soil conditions exert a decisive influence. "It is still undecided whether the seedling thereby becomes more susceptible to the fungus attack or whether this is not sufficiently explained by the fact that cold weather delays the growth and the plant remains unusually long

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1 Hollrung, in Zeitschr. f. Rübenzuckerindustrie i. D. R. Vol. 46. Part 482.

2 1 Centner in German weights equals 50 kg. or approximately 112 English pounds.

3 Bericht. d. Landw. Versuchsstation Posen. 1891.

4 Frank, A. B. Kampfbuch gegen die Schädlinge unserer Feldfrüchte. Berlin, Paul Parey, 1897, p. 117.

in an immature condition which is especially susceptible to the disease, while seedlings forced by heat pass rapidly through the susceptible stage and thus escape the danger."

In this explanation, after many modifications of Frank's original statement, is expressed the theory that besides this specific excitor of disease, Phoma, a definite degree of susceptibility of the beet seedling must exist for the production of rootblight. Sorauer held this point of view earlier since he proved that rootblight can exist without the presence of Phoma and that, instead of this, bacterial growth accompanies the disease. We owe the most thorough investigations of the bacteria of rootblight to Hiltner, whose recent studies we will consider with great thoroughness after sketching Stoklasa's theory. According to Stift's statements (loc. cit. p. 17) Stoklasa admits that bacteria can produce rootblight in beets, and he considers the following species capable of doing so:—*Bacillus subtilis, B. liquefaciens, B. fluorescens liquefaciens, B. mesentericus vulgatus* and *B. mycoides;* Linhardt declares the latter to be the essential cause of injury. Recently *Pseudomonas campestris* has been added to these. Stoklasa considers that the above mentioned atmospheric and soil conditions produce a *predisposition* in the beet seedlings. He turned his attention especially to *oxalic acid,* normally formed by the life process of the plant as potassium oxalate. Soluble oxalates, which act as poisons, are transformed into an insoluble calcium oxalate, if calcium oxide can be taken from the soil by the root hairs. By thus neutralizing the oxalic acid its retarding action on the process of assimilation ceases and the plant recovers. If much nitric acid is present in the soil or is added in excess *(strong fertilization with nitrate of soda),* an hastened development takes place at any rate, but at the same time the *oxalic acid content increases.* In such a case, if the young beet plant cannot take up sufficient calcium, it becomes predisposed to rootblight.

As already said, we owe the most thorough study of the relation of bacteria to this disease to Hiltner and Peters[1]. These investigators made a number of experiments and found that there are soils which almost never show any rootblight and, conversely, there are others in which the disease almost always appears. They concluded from this, that many soils are in a condition to lend a certain protective power and they perceive that this protective peculiarity is the ability of the immunizing soil to provide the outermost cell layers of the roots of the beet seedling with such micro-organisms as can prevent the penetration of fungi and bacteria producing rootblight. Hiltner and Peters call this protective sheath, which they had observed similarly in peas, *"Bacteriorhiza."* If its formation be prevented by sterilizing the soil and killing the protective soil organisms, in case the seed had not been previously sterilized, the fungi and bacteria causing rootblight could enter the young seedlings and destroy them.

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[1] Hiltner, L., and Peters, L., Untersuchungen über die Keimlingskrankheiten der Zucker- und Runkelrüben. Arb. d. Biolog. Abt. f. Land-und Forstwirtsch. am Kais. Gesundheitsamt, Vol. IV, Part 3, 1904, p. 207.

The words of Hiltner and Peters themselves best show how little the organisms per se are to be feared and how the chief cause of the disease is to be sought in the conditions making the plants susceptible. In speaking of the results of their experiments, they say (loc. cit. p. 249) "this result, however, shows that the production of diseased seedlings in the seed bed presents a rather complicated phenomenon. This cannot be laid exclusively to the fact (heretofore almost universally accepted) that parasitic fungi or bacteria accumulate on the seed balls, then passing over to the roots, *for these organisms in themselves cannot cause the diseased conditions of the beet.* Only after the resistance of the roots has been weakened by the influence of certain substances, viz., *oxalates, can otherwise harmless parasites attack them.*"

According to Hiltner's theory, the substances or circumstances predisposing a plant to disease are produced by the decomposition of the tissue in the seed balls, either on the field as a result of unfavorable weather, or later in storage because of too great warmth.

A work by Sigmund[1] reports upon the advance given to the occurrence of rootblight by the fact that the micro-organisms especially concerned in it (Phoma and *Bacillus mycoides*) find certain organic compounds in the nutrient solution of the host. After he had emphasized the fact that the parasites are not able alone to increase the disease, he mentions that the number of diseased beet seedlings can be increased if glycocol, uric acid, asparagin, hippuric acid, leucin, etc., are found in the nutrient solutions of the micro-organisms named and the beet balls are soaked in this nutrient solution.

In this important disease we have simply listed, first of all, the various theories and results of investigations as they have appeared from time to time, in order to show that with all observers, in spite of their very different points of view, one statement is found running through all their discussions like a red line, viz., the influence of the soil[2]. This influence shows itself most distinctly in heavy, binding soils. It can make itself felt also on other soils if they are encrusted for any reason whatever. The prime factor under such conditions is the scarcity of oxygen. At present we cannot say definitely what processes are started in the soil, seeds and the young plants. In the same way, no definite decision can be made as to whether rootblight is a constitutional disease, i. e. a deflection of the normal life functions leading to tissue decomposition, or a parasitic process, i. e. a process producing the same result but caused by the co-operation of micro-organisms. If, as we believe, in the majority of cases the latter should be granted, we must bear in mind emphatically the fact that these organisms, no matter whether fungi

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[1] Sigmund, Wilh. Beiträge zur Kenntnis des Wurzelbrandes der Rübe. Naturwissensch, Zeitschr. f. Land- und Forstwirtschaft, 1905, p. 212.

[2] Further material from practical sources may be found in the annual reports of the Special Committee for Plant Protection. (Jahresberichte des Sonderausschusses für Pflanzenschutz. Deutsch. Landw.- Gesellsch. 1892-1905).

or bacteria, can only destroy the seedlings where they have some predisposition to take up such organisms. This *predisposition* is the product of the soil in which they are grown under definite atmospheric conditions.

Therefore, the soil condition is always the first cause affecting the assimilatory process and inducing rootblight. The question whether this affection always takes place with an excess of free oxalic acid and whether the abundance of the acid acting poisonously is due to the formation of more acid by the plant body or that less acid is oxidized because of a scarcity of oxygen, may be left for later investigation. It is enough for our purpose to know that the disease is a result of a binding consistency of the soil under unfavorable atmospheric conditions, i. e. cold, wet weather.

We will now return to the statements of practical workers, who, from the beginning, have insisted that the cause of rootblight lies in the condition of the soil.

When citing these expressions, we come to the self-evident regulations for fighting it. Briem reports a case from the years 1904-1905[1]. On a newly broken field near Prague in 1904, with cold, wet weather, and a consequent slow growth, beets were extensively *root blighted* although until that time the phenomenon had been rare. Also, the beets did not revive completely until later. The same field in the following year, after a rich fertilizing with potassium, nitrates and phosphates, was again planted with commercial beets. As a result of the very wet, cold weather, the seed sprouted only at the end of two weeks (on the 24th. of April). It was feared that, with the weakened growth resulting from the cold nights, rootblight would again set in. Fortunately this did not happen and the warm days, coming at the beginning of May, soon caused the rapid, vigorous unfolding of the first pair of leaves. However, when, on the 20th of May, a violent rain had beaten the field down unusually hard so that water could only soak in very slowly, many seedlings showed the beginning of rootblight after five days. This example of the result of a sudden exclusion of the air from soil, beaten hard by rain, shows therefore that it is primarily advisable to keep the upper surface of the soil constantly open by cultivation. Secondarily, even if the soil contains lime, a further supply of quick lime must be given. The effect of the lime must not always be considered as a nutritive means, but as a mechanical one for improving the soil since it increases its friability. Superphosphate has given good results[2]. In fields liable to these conditions, increased attention should be given to the use of as vigorous seed as possible.

If one wishes to sterilize the seed which, according to our theory, is of very little advantage[3], a carbolic acid solution should be used. For the sterilization of one hundred and twelve pounds of beet seeds 1.5 k. carbolic

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1 Briem, H., Wurzelbrandentdeckung und kein Ende. Blätter f. Zuckerrübenbau v. June 15, 1905.

2 Zeitschr. f. Pflanzenkrankh., 1896. p. 54 and p. 340. Landwirt, 1896, Nos. 15, 17, 21. Jahresber. d. Sonderausschusses f. Pflanzenschutz, 1902.

3 Hiltner in Mitteil. d. pflanzenphysiolog. Versuchsstat. Tharand. Sächs. landw. Zeit. 1904, Nos. 16-18.

acid *(Acidum carbolicum liquidum crudum 100 %)* or the more expensive, pure crystallized acid in 3 hl. water. To test the acid's desired solubility, 0.5 grams should be shaken thoroughly in one litre of water; this should dissolve in from 5 to 10 minutes. When the sterilizing solution is ready, the seeds are poured into it and stirred about repeatedly and vigorously in the course of the next few hours. Then the seed is pressed down with weighted boards so that it remains entirely covered by the solution. After about 20 hours it is taken out and spread in a thin layer in an airy place and stirred often with a rake. As soon as it is sufficiently dry it can be planted with a drill, but it may lie for some time, when completely dry, without being injured.

If it is desirable to use the sterilizing solution several times, it is necessary only to replace the liquid lost by pouring in the needed quantity of a stock solution. However, considering the cheapness of the material, it is well not to use the solution too often[1].

Instead of sterilization, the coating of the seed with calcium carbonate seems to us to be advantageous.

But the main thing is to work the soil, for even the most carefully handled seed, found to be faultless in the germinating tests, can become diseased. Hiltner, in his above-mentioned work, gives some suggestions in this connection which are well worth consideration. Up to the present in trade, the quality of the seed has been tested according to its behavior in the seed bed, by means of a suitable method. It is now seen, that the number of diseased seedlings increases, the longer the seed is left in the seed bed. Experiments show that if, for example, the seedlings are taken from the sand seed bed on the 9th day, often more than ten times as many are found to be diseased as when taken out on the 6th day. To this it should be added that if the seeds lie close to each other the mutual infection is considerable. Besides this, the number of diseased seedlings differs greatly, depending upon whether the seed was soaked or not and whether distilled water, water free from calcium, or water containing calcium, was used for the soaking. If finally it is taken into consideration that the constitution of the soil decides the subsequent behavior of the seedlings, it will be concluded that the methods at present used for judging of the quality of the seed give no protection and no standard for beet seed. In order to obtain an insight into the germinating power, the best seeds will have to be tested in as many germinating seed beds as possible and with different methods[2]. The best germinating results, however, in no way give a guarantee as to rootblight. This depends upon whether the micro-organisms present in the dried blossoms, containing the seeds, find an opportunity of so developing in the soil that they can attack the young seedlings.

[1] Wilfarth, H., and Wimmer, G., Die Bekämpfung des Wurzelbrandes der Rüben durch Samenbeizung. Zeitschr. d. Vereins d. Deutschen Zuckerindustrie, Vol. 50, Part 529.

[2] For the difference in germination of the seed treated in the same way but sown in sand and in soil, compare the reports by Marek in the year Book of the German Agricultural Society. (Jahrb. d. Deutsch. Landwirtsch. Ges. 1892.)

Tropical Plants.

In consideration of my standpoint, that in much of our cultivation too little account is taken of the soil conditions, especially of its physical constitution, I think it necessary to refer also to the demands of tropical plants on the physical peculiarities of the cultivated land. In regard to tropical plants, I base my theory on the statements of Fesca[1] who has often given his own experiences, and further, on the recent publications of the Biological Agricultural Institute at Amani[2].

As we shall see, in these injuries, as in those in temperate climates, phenomena are often involved which are due to scarcity of oxygen manifested in heavy soil or in soils which have become compacted through cultivation. Many plants in the tropics can develop accessory organs with a scarcity of oxygen, like the adventitious roots from the trunks of trees buried or covered with slime. The palms (Phoenix, Kentia, Chamaerops etc.) can develop root branches growing perpendicularly out of the soil which have a peculiar respiratory arrangement (Pneumathodes); this appears as a mealy coating extending backward for a certain distance from the tip of the root. This mealy condition is produced by the increase, enlargement and breaking up of the outer layers of the rootbark with a rupturing of the epidermis and an almost complete suppression of the schlerenchymatic ring. Jost[3] determined experimentally with Phoenix that these pneumathodes remain in the soil when it is well aërated, but, on the other hand, are raised above the surface of the pot if it is submerged in water. Similar arrangements were found also in Pandanus, Saccharum and Cyperus.

Root-Rot of the Sugar Cane.

Among the numerous diseases of sugar cane, root-rot plays a prominent part. In Java it is considered the worst enemy of sugar cane culture. Naturally growers have not failed to cite the micro-organisms (*Verticillium (Hypocrea) Sacchari, Cladosporium javanicum* Wakker. *Allentospora radicicolà,* Wakker, Pythium etc.) colonizing on the diseased roots as its cause. Nevertheless Kamerling's[4] recent experiments have now confirmed beyond all doubt the supposition that a constitutional disease is concerned here,

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[1] Fesca, Der Pflanzenbau in den Tropen und Subtropen. Berlin Süsserott. Vol. I, 1904.

[2] As said above, the statements on the phenomena of disease in cultivated tropcal plants serve chiefly as proof of the necessary consideration of soil and atmospheric conditions as a cause of disease. In the descriptions we can sum up the material more briefly since abundant literature easily makes possible special studies. Besides the magazines already mentioned, pp. 65 to 67, the recent publications of the Usambara-Post furnish valuable material. "Der Pflanzer," Adviser for Tropial Agriculture" issued with the co-operation of the Biological Agricultural Institute, Amani, by the Usambara-Post, 1905. ("Der Pflanzer," Ratgeber für tropische Landwirtschaft unter Mitwirkung des Biologisch-Landwirtschaftlichen Institutes Amani, herausgegeben durch die Usambara-Post, 1905.)

[3] Jost, Ein Beitrag, zur Kenntnis der Atmungsorgane der Pflanzen. Bot. Zeit 1887, No. 37.

[4] Kamerling, Z., Verslag van het Wortelrot-Oenderzoek, Soerabaia, 1903, 209 pages, with 19 Plates.

resulting from compacting the soil. Raciborski with Suringar[1] has expressed the theory, earlier proved, that by transplanting sugar cane, which had suffered from this root disease, known as *Dongkellanziekte*, to other soil, the plants would become healthy. The disease occurs especially on heavy clay soils and manifests itself in Java, when at the beginning of the spring monsoon the plants die with alarming rapidity after they have already shown for some time an abnormal branching of roots and also deformed root hairs. He investigated the soils in which the disease occurred and found that they did not have sufficient friability and easily became compacted. The permeability of the soil can be increased by supplying humus, since this, as also ferric hydroxide, or silicate rich in iron, favors the formation of friable soils. Since the humus is gradually lost by oxidation, care must also be taken to retain the porosity of the soil by a renewed supply of stable manure, rice straw or green fertilizer (compost).

According to Wakker's[2] studies, many *leaf spot diseases* seem either directly produced by moisture in the soil (if of a parasitic nature) or favored by this moisture. Wakker found in the vicinity of Malang "a yellow streaked, banded disease," "rust," "ring spot disease," as well as the red and yellow spot disease. While he considers the first named as a parasitic phenomenon favored by moisture, he explains the yellow spot disease, in which the leaves acquire somewhat elongated, greenish yellow spots running into one another, as a hereditary constitutional disease.

Diseases of Cotton.

The majority of the cotton diseases may be considered at present to be of parasitic origin, but I doubt if this will always remain the case. With the conviction that many of the micro-organisms already found are to be considered parasites of weakness, naturally the first existing factor must be considered as decisive, viz., the disturbance in nutrition causing the weakness which first offers the possibility of infection by the fungus. This will have to be sought primarily in weather and soil conditions.

Examples of disease, in which only the soil is considered as the cause in the rainy season, are reported by Vosseler[3] from our East African colonies. In 1904, in the district of Kelwa, there occurred a *"browning of the stems,"* which produced greater damage in that region than all the other diseases which had appeared up to that time. Brownish black spots were produced in the bark below the tip of the main shoot, as a result of which followed the dying of this part as well as of the upper lateral shoots. The disease appeared, however, only on so-called sour soil.

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1 Kamerling, Z., en Suringar, H., Oenderzoekingen over onvoldoenden groei en ontijdig Afsterven van het riet als gevolg van wortelziekten. Mededeelingen van het Proefstation vor Suikerriet en West-Java, No. 48; cit. Zeitschr. f. Pflanzenkr., 1901, p. 274, and 1904, p. 88.

2 Wakker, J. H., De Bladzeikten te Malang. Archiev voor de Java-Suikerindustrie, 1894. Aflevering 1.

3 Vossler, Zwei Baumwollkrankheiten. Immune Baumwollsorten. Mitteil. Biolog.-Landwirtsch. Institut Amani, 1904, No. 32.

The red spot disease of the leaves, occurring to a devastating extent along the whole coast, was a second phenomenon. A pale border appeared along the edge of the leaves; the zone was distinctly cut off from the inner portions by a zigzag line. Dark red spots, or a uniform red coloration with which a deforming of the leaf surface was often connected, then appeared. The disappearance of this trouble with the appearance of drought indicates that the soil during the prevailing wet weather had unfavorably affected the growth of the cotton. Vosseler seems to suspect that the dreaded "wilt disease" should be included among the climatic diseases and refers in this to the possibility of producing immune races by growing plants from seed of healthy stock in diseased fields. According to Schellmann[1], cotton cannot grow on stiff clay soils and sour humus soils.

Castor Bean Cultures.

Although Ricinus thrives in subtropical and even in temperate zones, according to Zimmermann[2], it is extensively cultivated only in the tropics where it grows from sea level up to possibly 1600 m. The oily seeds are the desired crop. At any rate an abundant supply of nutriment is needed for Ricinus, since it makes very great demands on the soil. The plant also requires large amounts of water while growing. Later, however, the physical constitution of the soil has a determining value in the matter, since the plants do not thrive in all soils which, not well drained, remain constantly wet. These observations in the tropics correspond with our experience in growing Ricinus as a decorative plant. Only the plants develop well which have plenty of room and a porous soil, rich in nutriment. When grown in pots, to which much nutriment is added by fertilizing salts, the earth becomes encrusted and the plants remain small and weak.

Tobacco.

Very instructive examples of the determinative influence of the soil are furnished by Hunger's[3] observations on the development of the Delhi-tobacco and its different behavior toward the *"Mosaic Disease,"* which will be reported more fully in the section on enzymatic diseases.

Hunger says that a soil of white clay in which much sand has been mixed, is the best for thin-leaved tobacco if the amount of precipitation is favorable, but at the same time this also favors most the abundant appearance of the mosaic disease in the form of the so-called *"gay-head."* Here, after topping, the plant gives the impression of having made too rapid growth; long internodes, a yellowish-green foliage, a great many lateral shoots, all of which are sickly.

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[1] Der Pflanzer, Usambara-Post, 1905, No. 1. Here also older literature.

[2] Zimmerman, A., Die Ricinus-Kultur. Der Pflanzer, Ratgeber für tropische Landwirtschaft unter Mitwirkung des Biologisch-Landwirtsch. Institutes Amani, herausg. durch d. Usambara-Post

[3] Zeitschr. f. Pflanzenkrankh. 1905, Part 5. Hunger, as Botanist at the experimental station for Delhi-Tobacco (VIII Abt. d. Bot. Gart. zu Buitenzorg) has had at his disposal most extensive material for observation.

If the clay soil lacks sand, however, and becomes loamy, it is useless for tobacco culture. The roots of the plant develop scantily and are often deformed. The leaves are not of the right length and are of poor quality. The mosaic disease appears a week or two after transplanting. The red, atmospherically disintegrated soils of Ober-Langkat are pretty compact and here the plants are squatty; the leaves standing close above one another are not especially thin while the mosaic disease occurs rarely. It only appears exceptionally on the shoots which, after topping, develop sparsely.

On dark soils rich in humus, tobacco has an enormous, well-proportioned development; the very large leaves are dark green and thin. The mosaic disease abounds.

This disease scarcely, if ever, occurs on the peaty, porous, Paja soil, which has a high water-holding capacity. The enormous leaves almost never wilt in the soil containing much water, but are *very thick* and rich in oil; with fermentation they become dark colored and are therefore not very valuable. On fresh Paja soil the mosaic disease cannot be produced even by topping.

Coffee.

The tree, which of all our tropical plants deserves the most consideration, *coffee,* is extremely susceptible to soil conditions; although droughts are not favorable and it likes best to grow in soil which even at a time of drought keeps fresh, yet it withstands drought much better than too much moisture. If, during the rainy season, it is covered with water for only a few days, it becomes irretrievably diseased. A sufficient capacity for water in the soil, combined with abundant aëration, is therefore its chief need. Freshly cleared forest soil is found to be especially favorable for its cultivation. *Black rust (swarte roest)* and *canker diseases* (Natalkrebs and Javakrebs) *(Djamoer oepas)* with their diseased cambium are probably physiological disturbances introduced by unfavorable soil and atmospheric conditions and result later in fungus attack. The Liberian coffee is said to be less susceptible to impervious soil than the Arabian, and flourishes where the latter fails[1].

The leaf disease described by Zimmermann as *"Blorokziekte"*[2] seems to me also to belong here. The leaves develop convex, yellow spots. Later, the epidermis ruptures on these spots and the cell contents turn brown. The trees in Java, to be sure, are not killed by this disease, but their fertility is greatly reduced. As the result of an excessive water supply, Zimmermann observed[3] the so-called "little stars," occurring rarely in *Coffea liberica* and more frequently in *C. arabica*; i. e. blossoms which open prematurely when incompletely developed and therefore remain sterile. The disease should

1 Delacroix, G., Les maladies et les ennemis des caféiers. II édit. Paris, Chalamel, 1900, p. 8.
2 Teysmannia 1901, p. 419.
3 Eenige Pathologische en Physiologische Waarneminger over Koffie. Mededeelingen uit S'Lands Plantentuin, LXVII.

not be confused with the black discoloration of the blossom buds passing under the same name. These buds finally fall off unopened. Different kinds of root moulds have been described and considered as the cause of *root-rot*[1]. I think it will be necessary to study here the question whether parasitic fungous forms can attack the plant injuriously only when the roots have already been weakened by unfavorable nutritive conditions.

Cocoa and Tea.

Fesca says in regard to the *cocoa tree* "extremes of soil structure, poor sand, as well as tough clay, are not favorable to the cocoa tree. Rather it demands greater soil depth and freshness, without the necessity of enduring standing water, as well as greater humus and nutrition content, than does coffee." The same author, who himself has analyzed good tea soils in Japan, say of *tea*, that he found in a more compact soil, 30 to 40 per cent. of water as capillary water. Tea demands a sufficiently deep soil which is free from standing water, to which it is very sensitive. Here too a still little understood fungus is described as the cause of a root disease. It is said to result in the early death of the bushes, especially when growing on damp soil. Nevertheless Fesca[2] assures us that he has never yet seen the disease on well aërated soils. We might also trace the diseases of young tea plants described by Zimmermann[3] to an unfavorable place of growth, although a fungus bearing lobed haustoria has been observed at the disease centres. The leaves become flabby and discolored; the stems turn brown at the base or higher up where the root seems healthy. Often only the leaves show brown spots, especially on the midrib. The fungi developed from the diseased parts of the stem (Nectrieae) could not produce the disease even in infection experiments. In dry weather the disease decreases considerably. Also transplanting the seedlings from the closely planted seed bed arrested the disease. If we have considered here with the greatest brevity the soil demands of our most important cultivated tropical plants, it must still be added that naturally the climate remains the decisive factor. Among these climatic factors especial attention must be given to humidity since the quality of the harvest often depends considerably upon this. In cocoa plantations in Kamerun, for instance, it may be observed that the quantitative production of the trees is unusually abundant, but the quality of the fruit is only mediocre as the result of great dampness. The trees also are short-lived here.

Other Tropical Plants.

Of grains, *Maize* requires, first of all, a deep, mellow soil free from standing water and cannot thrive on tough clay. Sorghum behaves similarly, but is still more sensitive to cold and dampness and, because of its deep root

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1 Bolletim del Instîtto Fisico-Geographico de Costa Rica, 1901.
2 Loc. cit., p. 273.
3 Zimmermann, Untersuchungen über tropische Pflanzenkrankheiten. Sonderberichte über Lan- und Forstwirtschaft in Deutsch-Ostafrika, Vol. II, Part 1, 1904.

system, is very resistant to drought. This accounts for its growth on tropical and subtropical steppes. The Negro or brush millet *(Pennisetum spicatum)* is entirely unsuitable for firm soil, but is excellent for porous soils in dry localities. The other millet varieties behave similarly.

The *Leguminoseae,* which are suitable for growth as a second crop because of their usually short vegetative period, may, in the tropics and subtropics, acquire great importance not only as collectors of nitrogen and as an excellent nutritive substance, but are also valuable on account of their close shading of the soil, preventing it from hardening and as soil loosening, green manuring plants. The plants make good growth in dry soils;—accordingly heavy soils, in regions with abundant precipitation, are not suitable for them. Busse[1] has given more detailed studies of sorghum diseases and their relations to atmospheric conditions.

Of tuberous plants, the *sweet potato* requires about the same cultural conditions as our potato. The *cassavas* (Manniok) require deep, loose, dry soils, but rich in humus. The moisture-loving Maranta species, furnishing *arrowroot,* also requires looseness of the soil, on which account virgin soil is found to be less suitable because of its compactness. Even *Taro,* the tubers of the different Colocasia species, which requires a great deal of moisture, flourishes only when the soil is pervious. The same is true of the *Yam,* which is derived from different species of the genus Dioscora. In regard to poppy culture and the harvesting of opium, reference should be made to Braun's[2] work, and in regard to rubber plants and especially the Liana, root and herbaceous rubber plants, to studies by Zimmermann[3].

Means for Overcoming the Disadvantages of Heavy Soils.

Drainage. In this we have to take into consideration not only soils rich in clay, but also those sandy ones whose graular structure is so fine that they can become as closely compacted as clay soils.

Of the practical means used to increase soil aëration, *drainage* deserves to be named primarily. It facilitates the exchange of air in the soil interstices as well as removing stagnant water accumulations after every rain. The drainage pipe acts as an apparatus for sucking up air. When the rain fills the soil, it forces out the air which has a less oxygen content than the atmosphere, but is richer in carbon dioxid. But since the rain is quickly soaked through the drains, air rich in oxygen streams just as quickly from the surface down into the pores increasing, thereby, the processes of oxidation in the soil and the activity of the roots and micro-organisms needing oxygen.

The fear that drainage will impoverish the fields has rarely any foundation, since the numerous analyses of drain water show only slight traces of

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[1] Busse, Walter, Untersuchungen über die Krankheiten der Sorghum-Hirse. Arb. d. Biolog. Abt. f. Land- u. Forstwirtschaft a. Kais. Gesundheitsamte, Vol. IV, Part 4. 1904.

[2] Der Pflanzer, 1905, No. 11-12.

[3] Ibid, Nos. 8-10.

potassium and ammonia as well as phosphoric acid, which had been absorbed by the friable soil. Nitrates, because of their easy solubility, at any rate, are lost in larger amounts, but they are also partially washed away from undrained soil into the subsoil.

Further, the soil capacity for heat, increasing with drainage, should not be underestimated as well as the improvement of the crop produced, of which it may be said in general that damp, and therefore cold, soil produces crops poorer in nutriment. The reason why damp soil is *cold* is evident from considering the fact that if water has a specific heat equal to one, the highest specific warmth ever shown by soil is only equal to 0.5; i. e. at most half that of water. If this water which is the hardest to warm is removed by drainage, the soil must become warmer. Previous to drainage, the soil remained cold until late in the spring, thus causing a later awakening of vegetation and a later germination of the seed. A cold place of growth is especially disturbing to young plants, since it holds development back in a developing phase, which is determinative for the whole later plant. The root system becomes poor, the appearance sick, and later favorable temperature conditions are not able to overcome the bad condition. One of Stöckhardt's[1] experiments with winter rye may serve as an example. The experimental plots differed in drainage and soil porosity. One plot was traversed at a slight depth by a drain possibly 2.5 cm. wide and in such a way that the pipe, bent at right angles at one end of the drain, opened like a chimney toward the upper surface of the soil. The soil of this plot, as well as that of the undrained one, was broken up 50 cm. deep, while a third plot was dug only 25 cm. deep and not drained. In corroboration of earlier results obtained with lupin, oats and the like, the harvest showed an appreciable excess on the drained lot, although the young plants showed no difference before spring.

Reckoned per acre this crop amounted as follows:

	Grain kg.	Straw and Chaff kg.	Totals kg.
Part I, drained and dug 50 cm. deep	539	1470	2009
Part II, undrained and dug 50 cm. deep	411	928.5	1339.5
Part III, undrained and dug 25 cm. deep	338	859.5	1197.5

	Grain content per bu.	Nitrogen content of the grain
Lot I.	40.80 kg.	2.18 per cent.
Lot II.	39.85 kg.	1.83 " "
Lot III.	37.70 kg.	1.83 " "

Pätz[2], referring to the use of *drainage for removing iron from newly broken soil,* says, "usually iron is found directly under the surface of the soil and at the height of the usual ground water level. The ground water

[1] Chemische Ackersmann, 1859, p. 232; 1861, p. 100; 1864, p. 22.
[2] Hannoversche landw. Zeit. 1880, No. 45; cit. Biederm. Centralbl. f. Agrik.-Chemie, 1880, p. 911.

carries the iron upward and in many cases cements the sand grains in the soil at the usual height of the ground water level in such a way that often in laying a drain, a hard, stone-like, red soil is found. By laying drains correctly and systematically, with the horizontal drains intersected at right angles by the absorbing drains, the latter having at least a depth of 1.2 m. and the distance between every two drains being kept 10 times the depth, the level of the ground water will be lowered to the depth of the drain and no more iron will be carried to the soil above the pipes. The iron already present in the soil will be dissolved by the atmospheric precipitation and led to the dainage pipes or it will remain in the soil as the non-injurious oxid."

Working of the soil. Where there is no need of carrying away excessive water, *furrowing and deep plowing,* instead of drainage, will often serve the same end. In this care must be exercised if, with fertile, friable soil, there is a prospect of bringing a dead subsoil to the upper surface by the furrowing or plowing. In addition to fertilizing each time, the gradual deepening of the friable soil should take place at least over a period of several years. Since, with the deepening of the friable soil, the root surface becomes extended and, accordingly, an increased harvest takes place with a greater utilization of the soil, an increased supply of manure is demanded with the increasing loosening of the soil.

In soils inclined to crust, but otherwise not unfavorably constituted physically, *hoeing* and *hilling suffice* for increasing the soil aëration. This cultivation, which can scarcely be sufficiently recommended to the agriculturist and the gardener, and which can be used in any soil, regulates the soil moisture.

Some good, practical experiences as to the advantages of loosening the soil, may be found in the reports of the German Agricultural Society's special committee for the protection of plants (Landwirtschaft-Gesellschaft). We will cite a single example which is supported by comparative experimental cultures. In Skollmen[1] (East Prussia) Mentzel divided into two parts a field planted with mixed Swedish wheat, Epp wheat and Kaströmer wheat, and kept one half of it loose by harrowing after every rain,—i. e. by working with the narrow bladed cultivator,—but did not work the other half. Although its soil was better, the latter half yielded only 2160 kg. per acre, the former, however, 2650 kg.

A green manure fertilizer turned over deep in light soils and superficially in heavy soils, acts in the same way as this loosening of the soil surface. By means of this green manure the capillary raising of the water from the underlyng soil layers especially is interrupted[2]. On the one hand, the moisture is thus retained in the deeper layers of the lighter soil; on the other hand, in heavy, wet soils, a well aërated, friable surface is formed so

[1] Jahresb. d. Sond.-Aussch. f. Pflanzenschutz. Arb. d. Deutsch. Landwirtsch.-Ges., Part 107, 1905, p. 64.
[2] King, F. H., Tenth Annual Report of the Agric. Exper. Stat. of Wisconsin, 1884. p. 194.

that the seeds can germinate normally. The stronger, more sturdy plants, which have passed through the most critical germinative stages, are then better able to combat the soil moisture, which rises capillarily higher and more rapidly after the green manure has decomposed.

Freezing. The loosening of heavy soils in winter through a suitable freezing is of the greatest importance in their cultivation. If we take into consideration that water, when converted into ice, expands about one-eleventh of its volume, it is evident that the more closely lying soil particles are forced apart by the ice crystals. Also, since rocks are covered with a network of fine cracks, into which the water gradually soaks, the frost is constantly decomposing them and in fact the effects are greater as the freezing and thawing alternate during the winter. Naturally the rapidity of the action will depend upon the composition of the soil, i. e. on its water content. The smaller this is, the more quickly and deeply the frost can penetrate. Therefore, heavy and humus soils will freeze and thaw most slowly. Wollny's[1] experiments show the advantage accruing to the soil from the loosening action of the frost. He had two plots of land loosened up in the fall and left lying in *open furrows*, while a third was not worked. This plot and one of the two others were turned over in the spring while the third was worked only superficially. It was then proved that for the various plants cultivated, the yield was smaller from the plot which had not been left fallow in the fall, while the largest harvest was given by the one in which the open furrows froze during the winter and were broken up once more in the spring.

Mulching. We now come to the advantage derived in heavy soils from the *covering of the friable surface with litter*, after having considered earlier the protection given light soils by such a covering. The greatest advantage is that the covering substance prevents the compacting of the soil particles since it takes up the force of the rain drops and, conducting the water slowly, spreads it over the surface of the soil, thereby keeping the friable surface more porous. In nurseries the seed also germinates more uniformly in covered beds. The weeds do not grow so vigorously and can be more easily and completely removed, since they root more superficially in the looser soils.

The great air variations between day and night produce a heavy formation of dew in the porous covering material. This runs off to the benefit of the underlying soil and increases its fertility. If bark is used to a depth of 1 to 1½ inches, it furnishes a covering for the seed beds in winter and, in the spring, a protection against the penetration of frost and the cracking of the soil.

Seed and seedling beds should have water given them in June or July. In August the ground is harrowed and, in case the bark should then be covered too deeply, the exposed soil is covered with new bark. Snares for the control

[1] Wollny, E., Ueber den Einfluss des Winterfrostes auf die Fruchtbarkeit der Ackererden. Biedermann's Centralbl. 1902, p. 301.

of the unevitable June bug are made of heaps of scattered, moist bark which heats itself. The June bugs lay their eggs in these heaps which later, with a part of the underlying earth, are put in a wagon and worked up with peat, or lignite, ashes, lime, plaster and organic refuse to a compost pile, which, after a year or two, kills the grubs.

Harrowing.

Harrowing is a process which should find mention here. Anderegg[1] has published very noteworthy results of harrowing *meadows*. A meadow of uniform soil composition and mould was divided into four equally large lots. These yielded,—

(1). Unharrowed and unfertilized....... 377 kg. hay
(2). Unharrowed but fertilized.......... 833 kg. hay
(3). Harrowed but unfertilized.......... 770 kg. hay
(4). Harrowed and fertilized...........1563 kg. hay

Harrowing *winter sown grains* not only re-opens the encrusted soil, but also increase considerably the formation of young shoots. Director Conradi[2], however, justly points out the fact that the harrow is usuable only if the crust is not too thick and the soil not too binding. Also, if an encrustation in spring may be foreseen, the seed must be more thickly sown since harrowing destroys plants and the sand is thinned. For that reason harrowing is very useful occasionally in thinning the plants. The increased standing room for the plants left in place gives a greater supply of light to the basal nodes and starts the lateral shoots into a rapid growth and prevents their too rapid lignification when these buds obtain moisture from the earth heaped up by the harrowing. If the earth is not pulverized sufficiently by the harrow, the roller, and preferably a wheel roller, must be used in addition. In the majority of cases the roller will have to follow the harrow, because binding soils are not made absolutely fine by the harrow, and also because it is desirable that the earth torn away from the base of the plants may be pressed back again. The best time for harrowing depends on the development of the plant and the water content of the soil. If the plants have grown too far or continuous dry weather prevails, the harrowing should be omitted or, in the latter case, should never be carried out without a subsequent rolling.

A few words also might be pertinent here as to the *significance of stones in the soil*. In this connection, Wollny's[3] experiments have shown that with a high, constant air temperature (during the warmer seasons) soil covered with stones and mixed with them is slightly warmer than is that free from stones. With a falling temperature comes the reverse. During the daily minimum soil temperature, soil containing stones is for the most

[1] Illustr. landw. Vereinsblatt, 1880; No. 8; cit. in Biederm. Centralbl. f. Agrik.-Chemie. 1880, p. 693.
[2] From "Der Praktische Landwirt" in Fühling's landw. Zeit., 1880, p. 151.
[3] Wollny, Fühling's landw. Zeit. 1880, p. 814.

part colder than that free from stones, while during its maximum it is warmer. In regard to conditions of moisture, field soil covered with stones is found to be wetter during the warmer seasons than uncovered soil of otherwise similar composition. Soil covered with stones lets more water slip through than does one not so covered.

The Use of Lime, Marl and Plaster.

The importance of lime arises from its chemical action as a direct nutritive substance as well as from its properties, which change the mechanical constitution of the soil. Aside from favoring friability, it should be emphasized that the lime attacks the silicate in clay soils and sets free soluble potassium compounds. By its more rapid destruction of the organic substances, it causes a better decomposition of humus.

In regard to the technique in using lime, it is advisable to keep burnt (quick) lime in baskets under water until no more air bubbles arise (possibly 3 to minutes) and then to heap up the pieces in layers. They decompose (slake) of themselves and the lime stone, which lost its carbon dioxid in the previous burning, now becomes the white powdery calcium hydroxid ($Ca(OH)_2$) and as such represents slaked lime; which is soluble in 730 parts of cold water, and only in 1300 parts of boiling water (lime water). 100 parts of *quick* lime correspond to 132 parts of slaked lime. The lime should be uniformly spread over the field in quiet weather by hand, or with a suitable shovel. It is well to spread it in the fall on the stubble and then to work it under the surface. If it is necessary to wait until spring, it must be spread as early as possible before seeding, as soon as the soil has dried. Smaller doses (750 kg. to 1500 kg. per hectare) repeated about every five years, are more advisable than a single heavy liming, because, in the latter, the decomposition of the humus is so violent that the subsequent increase in the harvest is at the cost of a later production. It is said in practice that fertility is difficult to maintain on a lime-stone soil, because organic matter disappears rapidly.

Naturally the amount of lime depends upon the soil. Tough clay soil will bear most, while great care must be used with poor sandy soil. Soils which are lacking in organic matter or have water standing on them, may not be limed at all. The results which become evident most quickly are given by a humus soil poor in lime;—Sorrel *(Rumex acetosella)* indicates a scarcity of lime. Lime will act here splendidly as a fertilizer.

If local lime deposits be used, such as possibly meadow-lime or marl, or the so-called waste lime (gas lime, lime ooze, lime ash), it is distinctly advisable, before using it, to let the air pass through in order to decompose it, or still better, to let it freeze. When using waste lime one should convince oneself first of all, by a simple experiment, that no injurious secondary action can take place. According to Hoffman's experiments[1], it

[1] Mitteilungen der Deutsch. Landwirstchafts-Ges. 1905, p. 367.

should also be taken into consideration that the more lime used, the less should fertilizing with potassium be neglected. In using stable manure, it is well to put the lime in the soil sometime before the manure is added. Bone meal should be avoided on soils containing lime. In the same way, it is not advisable to use ammonia and ammonia superphosphates together with lime. Pulverized quick lime should be used on binding, clayey soils; lump or slaked lime on better loam soils.

In regard to the need of lime by the different plants, Hoffmann states that the Leguminoseae in general are distinguished as the most responsive to applications of lime, but that the Lupines and Serradella may be considered as hostile to lime and sweet peas also do not like the direct use of lime or marl.

In the *use of marl* also, the lime is the most active principle and hence it follows that a clayey soil, rich in humus, bears marling better than a poor sandy soil which in turn can be more benefited by a clay marl than by a lime or sand marl. The sometimes dreaded *"impoverishment"* from the use of marl will take place only if fertilizing with stable manure is delayed. The last is indispensable for all soils and especially for heavy ones in keeping the fields productive. No mineral fertilizer can replace stable manure.

The influence exerted by the lime contained in marl upon decomposition of the humus substances is illustrated very clearly by Petersen's[1] experiments. He determined the amount of carbon dioxid produced in different soils by the process of decomposition with and without the addition of calcium carbonate. In using a heavy clay soil, known to be perfectly sterile, with 1.98 per cent. humus and 36 per cent. of its water holding capacity in water content, he obtained in 16 days 0.07 per cent. of the weight of the dry soil in carbon dioxid. On the other hand, the same soil under the same conditions with the addition of ½ per cent. of calcium carbonate, mixed in the clay as marl, yielded 0.20 per cent. carbon dioxid, or per liter of dry soil, without addition of lime, 0.9153 g.; per liter of dry soil, with addition of ½ per cent. lime, 2.6167 g.

A leaf mould with strongly acid reaction consisting of 58 per cent. humus and 30 per cent. of the absorptive capacity in temporary water content, yielded after 16 days, without and with the addition of 1 per cent. calcium carbonate (when the earth still gave an acid reaction): per liter of dry soil, without the lime addition, 0.8911 g. CO_2; per liter of dry soil, with the addition of 1 per cent. calcium carbonate, 3.386 g. CO_2.

With the addition of 3 per cent. calcium carbonate, the soil yielded 5.3476 g. carbon dioxid, while the series of check experiments, free from lime, produced only 0.9664 g. CO_2. The addition of the lime, therefore, had caused 3 to 4 times as great a production of carbon dioxid, i. e., humus decomposition, as in the soil in an unmarled condition.

Heiden, in Pommritz, summarizes thus the effect from the use of marl: The chemical action arises primarily from its content of calcium carbonate

[1] Jahresbericht f. Agrik. 1870-72. Landwirtsch. Versuchsstationen, Vol. 13, p. 155.

and consists in the hastened decomposition of the organic elements of the soil, in the combining of the free acids so injurious to plant growth, in the conversion of ferrous oxid into ferric oxid, and in bringing about the absorption of the basic nutritive substances by the soil. The bases are held in the soil as hydrated silicates and as the salts of humic acid. In the absorption of the bases by the humus body, these must be present combined with carbon dioxid. The lime promotes the formation of carbonates. Further, the mineral elements of the soil are decomposed, whereby the basic nutritive substances are freed and made accessible to the plant. Every marl does not suit every soil,—clay soils, where possible, must have a lime or sand marl.

Aside from these indirect advantages, the direct effect of the use of marl is shown in the addition of potassium, soluble silicic acid, magnesia and phosphoric acid, which, together with lime, are present in every marl.

A few words should be added here as to the *use of plaster or gypsum.* Franklin's words,—"This has been plastered," are well-known. He wrote this in plaster on a clover field in order to recommend to his countrymen the process which had been known with great advantage by the Romans (Knop, Kreislauf des Stoffes) and the Greeks. According to Knop's experiments and those of Déhérain and Liebig, a solution of plaster in soils containing absorbed potassium, frees it in the form of sulfate, while the lime itself is precipitated. The method of spreading the plaster on clover plants freshly covered with dew or rain, recommended by experience, is found to be advantageous, since a solution of plaster is formed on the moist plants; dripping from them, it acts at once in the immediate vicinity of the roots. It thus rapidly becomes of advantage to the bacterial flora, for Pichard's[1] researches and those of others show that plaster and other sulfates (potassium and sodium) exercise a most favorable influence on the process of nitrification. Plaster should be used in an unburned state and indeed for clover and lupines from 2 to 5 centner per acre in the spring.

Although the influence of calcium hydrate or carbonate, favoring decomposition, was discussed above, it must still be emphasized, that, as shown by Wollny's[2] work, this is only of value when the substance is already decomposed and contains humic acid, while the addition of calcium on undecomposed organic substances rather hinders decomposition. This is especially true for calcium sulfate (gypsum) which comes under consideration as a conservation material for animal manure. In a mixture of quartz sand (300 g.), powdered peat (5 g.), and 60 ccm. water, Wollny[3] found

Volumes CO_2 in 1000 Volumes Soil air—

	without the addition of gypsum	with the addition of gypsum	
	....	0.05 g.	0.1 g.
CO_2	3.194	3.029	2.713

[1] Annales agronomiques X, p. 302.
[2] Wollny, E., Die Zersetzung der organischen Stoffe etc. Heidelberg, Carl Winter, 1897, pp. 133 ff.
[3] Journal f. Landwirtschaft, 1886, p. 263.

The addition of the plaster had accordingly reduced the loss in organic substances and also in nitrogen; i. e., had exercised an arresting influence on decomposition. The use of calcium compounds as a remedy against diseases, in which an excess of nitrogen comes under consideration, will be discussed under the individual cases of disease.

3. THE DISADVANTAGES OF MOOR SOILS.

The Acids in the Soil.

Ramann[1] explains as moors,—the formation of more moist regions in temperate zones, in which *soils poor in nutritive substances, with an acid reaction,* are covered with dwarfed bushes, grasses, mosses and peat-moss (sphagnum), and also lichens.

The humic acids* act freely here, and cause the acid reaction of the soil. Acids are formed by the decomposition of the organic substances in the soil to which fungi as well as bacteria surely contribute a share (Cephalosporium, Trichoderma, etc., according to Koning[2]). Formic acid, acetic acid, butyric acid, etc., are produced which decompose rapidly in well aërated soils. Besides these, however, the humic substances also form the still little known *crenic acid* with its salts (crenates) which, widely distributed in soils and water, form a yellow, strongly acid solution. drying to an amorphous mass. While its salts with alkalis and alkaline earths are soluble, its ferric oxid remains insoluble. With the entrance of air aprocrenic acid is produced from it, the salts of which are either insoluble or dissolve with difficulty. A great influence on the weathering and the transportation of the accessible mineral salts may be ascribed to these acids and their compounds[3]. Raw humus, peat and other soil substances with a strong acid reaction lose only a part of their acids even after lying sometime exposed to the air. Since even well aërated forest soil often shows an acid reaction, it may be concluded that scant oxidation either does not cause the production of the soil acids, or only at times produces them. We must consider here also the work of definite bacteria in this acid formation. Free acids are often absent in good soils, but poorer moor soils are frequently rich in them and become even poorer because extensive leaching and weathering processes constantly take place, due to the free acids.

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1 Ramann, Bodenkunde, 2nd. Edition. Jul. Springer. 1905.
2 Koning, Arch. néerland. sc. ex. et nat. 1902 II, 9, p. 84.
3 Ramann, loc. cit. p. 144.

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* In the light of recent investigations on the nature of the organic matter of the soil it seems that we must revise some of the older terminology. The term "humic acids" is rather to be regarded as a loose generic term applicable to a group of organic compounds found in the soil.—Vide:—

Mulder, The Chemistry of Vegetable and Animal Physiology, trans. by Fromberg, 1849.

Schreiner, O. and Shorey, E. C., Bulletins 53, 74, and 88, Bureau of Soils, U. S. Department of Agriculture.

Jodidi, S. L. Jour. Amer. Chem. Soc. 34: 94. 1912; Jour. Franklin Inst. **175**: 245. 1913.

(Translator's note)

In regard to the sensitiveness of our cultivated plants to free acids, Ramann cites Maxwell's[1] experiments with 1-10 and 1-50 per cent. solutions of citric acid. He found that all the Cruciferae were quickly destroyed, the Papilionaceae more slowly. Grain suffered greatly, only the pearl millet and maize could withstand it. Tolf made discoveries in regard to humic acids, according to which seedlings suffer in acid moor soils. In the acid moor, the diffusion of the salt solutions is sharply arrested. According to Reinitzer and Nikitinsk, *pure humic acids* are unsuitable for the nutrition of bacteria and fungi. On the other hand, most of the higher plants can endure a moderate amount of these acids. We discover from our cultures of Ericas, Azaleas, Rhododendrons and other Ericaceae in moor soil that a number of plants indeed seem directly adapted to acid soils.

The dark colored humus parts consist preponderately of *Humin and humic acid* (*Ulmin,* according to Mulder). The humus substance must be considered as a mixture of closely related bodies with and without nitrogen, which can be separated into two groups according to their behavior with alkalis. The brown humin substances, insoluble in the most diverse solvents, swell up in alkaline liquids and pass gradually over into humic acids. The humic acids (their chemical composition is insufficiently known), containing possibly 59 to 63 per cent. C, 4.4 to 4.6 per cent. H. and 35 to 36 per cent. O, are easily dissolved in alkalis and are re-precipitated from their solutions by stronger mineral acids. If they are withdrawn from acid soils (moor soils) with alkalis or ammonia and precipitated with hydrochloric acid, a voluminous, jelly-like substance is obtain which, in drying, forms a brown or black amorphous mass. The humic acids are separated from their solution, by freezing, in the form of a dark colored powder, which gradually passes over again into solution. Ramann emphasizes the fact that humic acids are somewhat soluble in pure water, but not in water containing salts. The salts of the alkalis and of ammonia with humic acids are soluble in water, but not those of the alkaline earths (calcium and magnesium). Yet the latter also seems to become soluble with an excess of acids. Calcium humate will decompose quickly into calcium carbonate which will combine into new masses of humic acids.

On an average, the nitrogen content of humus substances is greater in dry regions than in moist ones. By the advancing decomposition, the nitrogen, which in organic combinations is accessible to plants with difficulty, is carried over into compounds easily absorbed.

Raw Humus.

Humus is beneficial and indispensible only where, in pure deposits or mixed with the mineral skeleton of the soil, it is exposed to *constant aëration* and to sufficient moisture. Its chief action on plant growth does not lie in its nutrient content or in the carbon dioxid formed by its decomposition of minerals, but in its physical properties.

[1] Journ. Amer. Chem. Soc. 1898, 20, p. 108.

If humus is mixed with dense soils, they are loosened and made warmer and more easily worked. In sandy soils the humus acts as a binder and increases the water capacity, whereby the fluctuations in temperature become less marked. These favorable peculiarities, which arise from the *mixing* with mineral elements in the soil, disappear as soon as the humus is deposited on the soil in *impervious layers, i. e.,* is not broken up by abundant decomposition and the micro-organisms. In compact humus layers, the content in free acids is almost always greater. The forest soils, which are most rapidly decomposed and worked up, are the best. In warm climates the work progresses very quickly of itself.

With a favorable humus decomposition, we find that in forest soils the porous forest débris, which forms the layers of *litter,* is not so thick and merges gradually into a friable, strongly decomposed, structureless humus layer. If in any region the factors contributing to decomposition are absent, these layers of litter are retained, settle only gradually and become a firm, fibrous humus mass, which is deposited on the subsoil and remains more or less sharply separated from it. Such cases may be observed in poor sandy soils, especially those containing meadow ore.

This process, in which therefore the organic substance acquires no earthy composition, will occur everywhere where conditions unfavorable to decomposition exist,—as, for example, when the air is excluded by water, or conversely, with too great drought in the hot seasons or in places exposed to constant strong winds.

Our forest tracts, where heather *(Calluna vulgaris),* cranberries and huckleberries (Vaccinium) the pteris and aspidium brakes and the cushion-forming mosses grow, are most inclined to the formation of such fibrous and but slightly earthy humus layers, the undecomposed elements of which are deposited in dense masses on the soil and in this way form the so-called *"raw-humus."* The upper layer of such raw-humus deposits still shows the interwoven structure of the plant débris, the lower layer, in which the plant parts are but slightly distinguishable from one another, has a *fibrous* dark humus substance interwoven with roots. In moist beech, pine and spruce tracts, such raw humus may become peat-like.

Ramann (loc. cit. p. 162) states as his opinion of the change in the soil beneath a covering of raw humus,—that, besides the exclusion of air, the humic acids especially form the injurious factors. These act on the unweathered silicate, decomposing it energetically, bringing into solution alkalis and alkaline earths and, since at the same time the amount of acid solutions absorbed in the soil is slight, *leaches the soil,* i.e., the soluble substances are carried down to greater depths. If raw humus lies on sandy soils, the grains of the uppermost layer appear to be strongly bleached and milk-white, the intermixed silicate rock is greatly weathered and usually transformed into white kaolin. The humus admixture still richly present on the upper surface decreases more and more from the top downwards so that

the soil becomes light gray in color and, because of this color, is called *gray* or *lead* sand.

Below this light colored layer is found, sharply separated from it, a yellow to brownish looking soil, the deeper layers of which gradually become lighter. Here, the sand grains show mixtures of ferric-oxid or ferric hydrate. Then comes the white raw sand, still but little affected by weathering. The uppermost humus soil layer is found to be most weathered and the layer most impoverished by leaching. If the leaching of such an upper soil layer, under the influence of the raw humus deposited on it, be carried to a given stage, the action of the salts in the soil on the soluble humic acid must cease, the salts then remain in solution and can penetrate to the lower layers of the soil. If they come in contact here with soluble salts, they are precipitated and coat the separate soil grains with a structureless layer of organic substances. Under the microscope, I found the sand grains covered with brown, chart-like etchings. If this process keeps up, the precipitated organic substances finally cement the separate sand grains into compacted layers below the lead sand,—*meadow-ore* has been produced.

MEADOW-ORE.

According to Ramann's explanation of the production of meadow-ore, given in the previous section, this is a ***humus sand stone***. It occurs in various forms and first of all as *"Branderde"* or *"Orterde,"* which has a white easily pulverized form and shows a large content of organic substances. This is formed in rich soils which are but little changed unfavorably. The real swamp ore is a firm, stone-like, hard mass, deposited on easily pulverized or loose soil layers, with a medium content of organic substances and a brown to black color. This is the form most widely distributed in North Germany (Lüneburger moor). Besides this, there is a lighter brown swamp-ore which is very firm and tough and holds but small amounts of organic substances. This is the hardest form, offering the greatest resistance to a working of the soil and frequently occurring in great thickness.

In judging the processes of leaching, an analysis taken by Graebner[1] from Ramann's[2] work may be useful. The swamp ore soil in the Main Forestry District Hohenbrück in Pomerania contained in its different layers:—

(a) *Lead sand,* which was 15 to 20 cm. thick and contained 1.05 per cent. of organic substances[3].

	Soluble in Hydrochloric acid.	Residue *insoluble* in Hydrochloric acid.
Potassium	0.0076 per cent. of the soil	0.618
(Sodium	0.0111 " " " " "	0.167)
Calcium	0.0110 " " " " "	0.060
Magnesia	0.0026 " " " " "	0.020
(Manganous oxid	0.0032 " " " " "	0.060)
Ferric oxid	0.0964 " " " " "	0.450
Aluminum oxid	0.0268 " " " " "	0.650
Phosphoric acid	0.0058 " " " " "	0.043
Total content except silicic acid	0.1645	2.068

1 Paul Graebner, Handbuch der Heidekultur. Leipzig, Wilh. Engelmann. 1904, p. 194.
2 Die Waldstreu, Berlin, 1890, p. 30.
3 Ramann in his "Bodenkunde" 1905, p. 166, gives the same analysis without the elements enclosed in parantheses.

(b) *Swamp* ore, 5 to 8 cm. thick with 7.28 per cent. of organic substances:

	Soluble in Hydrochloric acid.	Residue *insoluble* in Hydrochloric acid.
Potassium	0.0178 per cent. of the soil	0.754
(Sodium	0.0033 " " " " "	0.360)
Calcium	0.0194 " " " " "	0.170
Magnesia	0.0137 " " " " "	0.028
(Manganous oxid	0.0044 " " " " "	0.047)
Ferric oxid	0.1936 " " " " "	0.690
Aluminum oxid	1.5266 " " " " "	2.320
Phosphoric acid	0.2956 " " " " "	0.042
Total mineral substances except silicic acid	2.0744	4.411

(c) *The yellowish brown sand* underlying the swamp ore:

	Soluble in Hydrochloric acid.	Residue *insoluble* in Hydrochloric acid.
Potassium	0.0085 per cent. of the soil	1.103
(Sodium	0.0213 " " " " "	0.528)
Calcium	0.0254 " " " " "	0.225
Magnesia	0.0401 " " " " "	0.064
(Manganous oxid	0.0068 " " " " "	0.026)
Ferric oxid	0.3448 " " " " "	0.760
Aluminum oxid	0.4000 " " " " "	3.210
Phosphoric acid	0.0281 " " " " "	0.043
Total mineral substances except silicic acid	0.8750	5.959

We perceive from the above figures that, by leaching, the lead sand has not only lost in soluble substances, but that the greatest part of all the rock débris containing nutritive substances has been decomposed by weathering and being washed deeper down. It is therefore a fact that certain soil layers in forests and in open moors (usually formed from such soil layers) become impoverished. This is very significant agriculturally if the impoverishment exceeds the supply of nutriment furnished by weathering and the annual rain fall.

Meadow ore must be distinguished from the *real swamp ore;* the former is insoluble in an acid solution, such as hydrochloric acid, while the swamp ore is abundantly dissolved.

Especially in humus moor soils, where the deposition of raw humus leads to the formation of swamp ore, do two chief injurious factors come under consideration:—the lack of oxygen due to the density of the soil and the content in humic acids. The processes taking place, with an exclusion of oxygen, have been considered in another place (for example, p. 99). We have here to take only the humic acids under consideration. Graebner pays the desired attention to this point[1]. Continuing Wolf's[2] investigations on

[1] Loc. cit. p. 228.
[2] Tagebl. Naturf. Vers., Leipzig, 1872.

the wilting of the leaves and their ultimate death, resulting from the detention of the plant roots in water excessively charged with carbon dioxid, Graebner cites Maxwell's experiments[1] with citric acid and those of Tolf and Blank with humic acids, all of which lead to similar results. This is the place to record Ramann's statement as to the cause of retarded diffusion in acid soils. Either the colloidal composition of the moor-substances can reduce the capacity for diffusion and the colloidal substances are precipitated by neutralization with lime, or some direct action of the humic acids is present. If one thinks of the discoveries showing the influence exerted by slight acid increases on the protoplasm[2], whereby its currents are arrested, one must consider the direct action of the acid to be of the chief importance. Special proof already exists of the retarding of transpiration by acids (tartaric, oxalic, nitric and carbonic acids, etc.) and its hastening by alkalis (potassium, sodium, ammonia)[3]. It can therefore be said, with Schimper, that plants in a strongly acid soil will suffer from *physiological drought* even in the presence of abundant water. To this must be added that the great power of humus to retain water makes the mechanical withdrawal of the water from the soil particles much more difficult for the roots than if in sandy soil. Plants are found to wilt in peaty soil or loam with a percentage of water sufficient to keep them perfectly fresh in sandy soils, as Sachs'[4] experiment has already shown.

All these injuries due to the soil find expression most of all in the cultivation of pines, which subject Graebner[5] has treated with especial thoroughness. He found in young pine plantations, which had grown tolerably well for some years, that the shoots formed in May at first developed normally, but, with the appearance of the summer drought, became grayish green in color. If the dry period continued, the shoots begin to curl, the needles of the previous year became blunt and brown and in many cases the little trees dried up in a few weeks. By digging in the soil, it was found that swamp ore had been formed *below* the roots or even around the still rather slender ones.

To supplement his description, Graebner pictures in the figures here reproduced root development on swamp ore soils. We see in figure 29, that the strongest and longest roots are spread out not far below the surface of the soil and parallel to it, so that its nutrition must take place through the raw humus and the lead sand, which is poor in nutritive substances. Since root development is greater in solutions poor in nutritive substances than in concentrated solutions, this results in a wide reaching out of the root branches, which, in the present case, according to Graebner, seem several meters long and but little branched. The aërial axis, however, is scarcely a

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[1] Journ. Ann. Chem. Soc. XX (1898) p. 103.
[2] Pfeffer, Pflanzenphysiologie II Vol. 1904, p. 798.
[3] Pfeffer, Pflanzenphysiologie I Vol. p. 231.
[4] Sachs, Handb. d. Exp.-Physiol. Leipzig, 1865, p. 173.
[5] Graebner, R., Handbuch der Heidekultur, Leipzig, 1904, W. Engelmann, p. 231.

meter high. Poverty in nutritive substances in combination with the lack of moisture, easily becoming great in lead sand, are the causes of an ultimate blighting at the tops.

Figure 30 shows the root growth of an oak. The oak was planted after the layer of swamp ore had been broken through artificially. But this layer of swamp ore had later re-united and the portion of the root in *g*, nearly shut away from an air supply, had practically stopped growing. No mycorrhiza, or scarcely any, could be found on this part of the root.

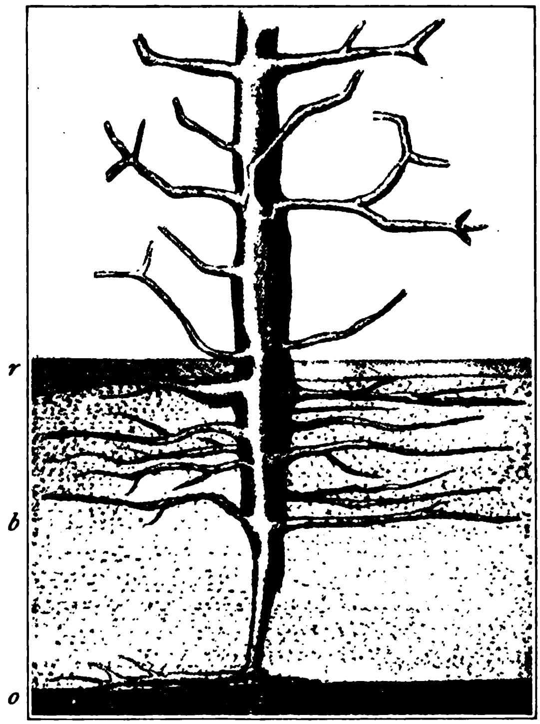

Fig 29. "A meadow ore pine" from the Lüneburger moor, grown after the formation of the meadow ore.

r raw humus, *b* lead sand, *o* meadow ore. Below the meadow ore the yellow sand begins. (After Graebner.)

Graebner attaches the following significance to such phenomena. If the swamp ore is deposited below the roots, the earth lying above it is naturally exposed to great *fluctuations in moisture,* and in times of drought becomes so dry that the plants die from a lack of moisture. In cases of this kind, however, the plants forming their roots entirely in the lead sand, exhibit a very weak growth, gradually making itself evident by short, yellow needles. If the swamp ore, however, lies directly around the roots, which are about as large as knitting needles, and have penetrated in to the better soil, it presses against them, causing knotty swellings. This takes place if the roots reach the better subsoil through an opening in the swamp ore layer. Such mechanical constrictions disturb further root growth. The tree is therefore essentially dependent on the roots lying above the swamp ore layer. Growth and vital activity are normal during the spring dampness, but all activity stops if a hot summer dries out the soil. Graebner found the *root tips shrivelling,* turning to resin or dying entirely. In larger trees, with a renewal of moisture, time and material are necessary for new root growth. This loss in time and substance becomes evident in the growth of the aërial axis and, in combination with the results of the period of drought, causes in great part the weak growth of the moor pines. The plantations improve as soon as the fluctuations of moisture are less extreme.

Usually pines on high moor soil develop a very crooked form[1]. Yet the seeds of these crippled pines, after the moor has been drained dry, grow into erect trunks. Schröter and Kirchner[2] also state that, on too wet places in the high moor, *Pinus montana* makes a reduced cripple growth ("Kusseln"), but recovers after the water has been drained from the soil. Our pines form such ("Kusseln") also on wet meadows. In the cases I have observed, this form of growth was produced by the resinification of the terminal bud of the main shoot, because of insect and fungus injury; there then develops below this bud a number of shoots which remain short (and in part some rosette shoots).

Figure 31 shows a pine 48 years old which came from the Lüneburger moor and which Dr. Graebner most kindly placed at my disposal. The height of the whole tree,—including the tops and measured from the root neck up, amounted to 74 cm.; the length of the trunk up to the first branch, 39 cm.; the girth of the trunk below the lowermost branch, 8.3 cm.; the average length of the needles, 2 cm. The foliage of the whole tree is very sparse. The needles have remained only on the latest shoots, all the older ones have fallen. The branches are greatly thickened in places and cracked open as a result of injury from frost. The perpendicularly growing tap root is 8 cm. long to its place of horizontal bending; the largest horizontal root branch, 18 cm. The branch growth is sparse and the branches have sharp angles (*k*) and often dead tips (*a*). These sharp angles or bow-like curves (*k*) arise because the branches and the main trunk have received one-sided, canker-like frost wounds to which correspond an increased wood formation and a stretching on the opposite side. Greater frost wounds, extending over more than half the circumference of the axis, are found at *f* and *f'*.

Fig. 30. An oak from the Lüneburger moor planted after the meadow ore had been broken through. The layer of meadow ore had closed later.

r raw humus. *b* layer of sand 20 cm. thick. *o* meadow ore. *g* yellow sand. (After Graebner.)

[1] v. Sievers. Ueber die Vererbung von Wuchsfehlern bei Pinus silvestris. Forstl.-naturwiss. Zeitschr. 1898. Part 5.

[2] Lebensgeschichte der Blütenpflanzen Mitteleuropas, Part III, 1905. p. 222.

In figure 32 *f'* on the main trunk is reproduced in natural size, in order to show that, like "open canker," the wounded surface consists of many very small, over-growth edges of different years which recede like terraces.

In accordance with the paltry branch growth in figure 31, the root is also small; it cannot follow its natural tendency to send its tap root downward

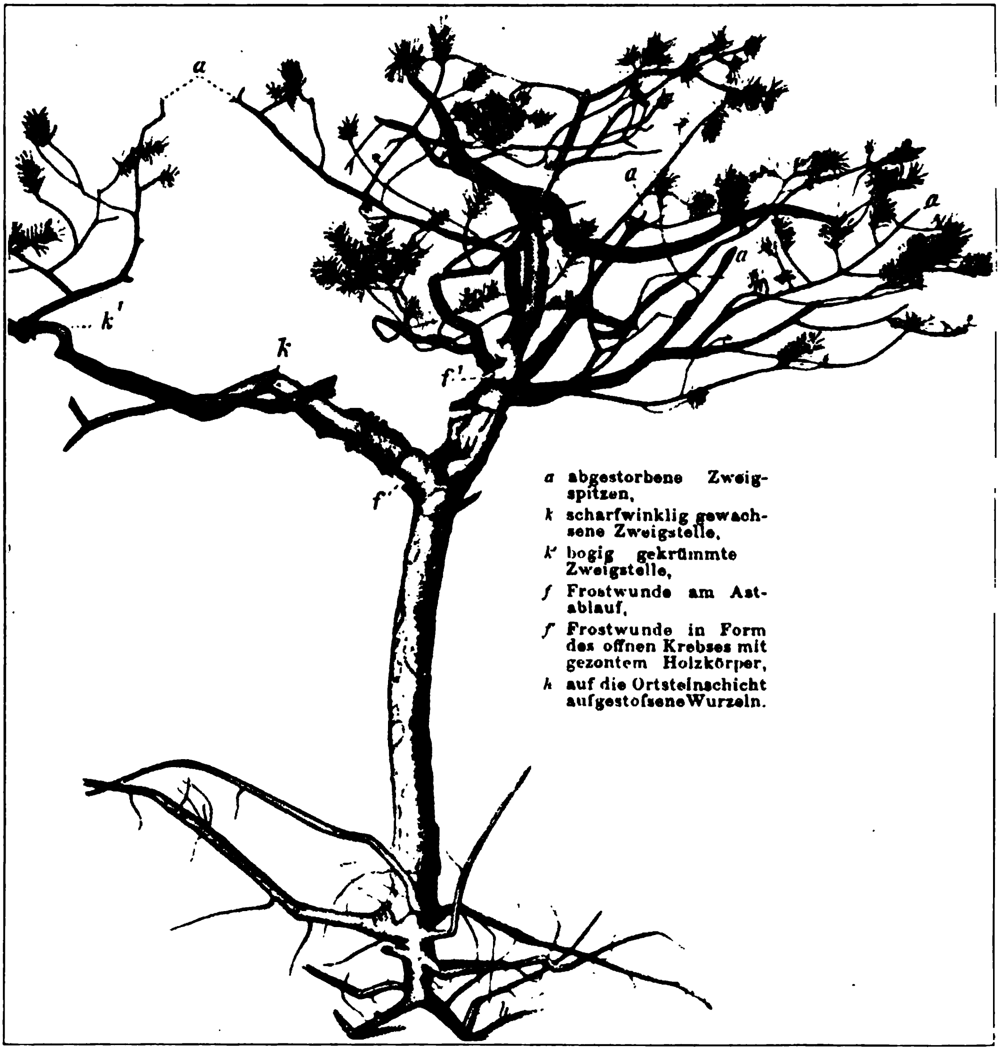

Fig. 31. A moor pine with flatly extended roots from the Lüneburger moor. (Orig.) *a* dead tips of branches, *k* parts of the branch which have grown out at sharp angles, *k'* parts of the branch curved like bows, *f* frost wound where the branch leaves the trunk, *f'* frost wound in the form of an open canker with a distinctly limited wood body, *h* roots which had grown against the layer of meadow ore.

perpendicularly (compare figures 5 and 6, p. 95), but must extend its root branches in the upper soil layers and moss cushions. Part of the lowest root branches are partially bent upwards at a sharp angle, probably because they have met with a layer of swamp ore or some similar impenetrable body.

In his study of the high moor of Augstumal in the Memel delta, Weber[1] gives very interesting illustrations of the crippled forms of pines. corresponding to the *Pinus silvestris f. turfosa,* Willk. Here he describes also the crippled birches, whose roots, like those of the Scotch fir, always show splendidly developed mycorrhiza. The trunk, usually only a few centimetres thick, is mostly bent and knarled, and covered below with a *seamed bark,* a very striking feature in such small trees. To this it should be added that these small birches usually only about 1.5 m. high form a well set top. On an average, the main root penetrates only 15 to 20 cm. into the soil, then bends to one side, to run parallel with the surface. The roots, spreading sidewards, attain to 3 to 4 times the length of the trunk. The vegetation on the high moor is best characterized by a specimen of *Betula pubescens* described by Weber[2]. The upper trunk, which had white rot at the top, was 1.8 m. high; the wood from which the bark had been removed was possibly 34 mm. in diameter above the root neck and had 51 annual rings, the last eleven of which altogether were only 0.9 to 2.6 mm. wide. The little tree was just beginning to become blasted at the top and was overgrown for 30 cm. above the root neck with *Sphagnum medium* and *S. acutifolium.*

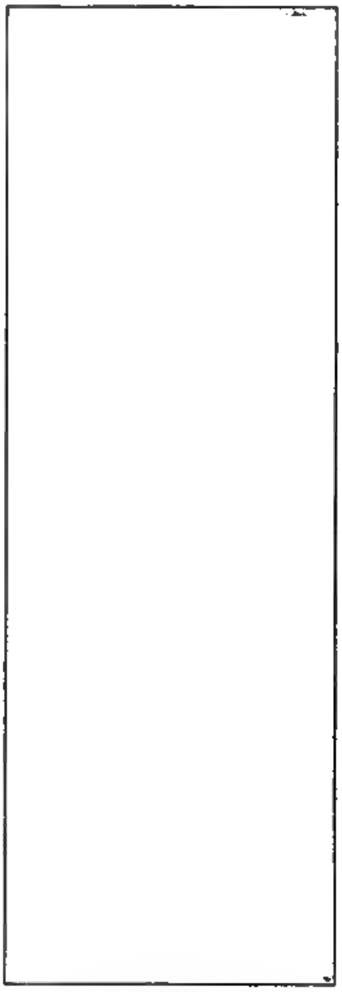

Fig. 82. Canker-like, wounded place on the moor pine.

c the (deepest lying) wood centre. *t* edges of the wound rising like terraces in which the most recent, *j*, are the most rolled back and the old bark, *r*, covering it, which is breaking loose in squarrous pieces. *w* dying, outermost edge of the wound. *l* lichen growths. (Orig.)

In cultivation, it is not only necessary to break through the swamp ore layer, but also to bring it up to the surface of the soil. In the air, it decomposes to a brown sand, which gradually becomes lighter in color because the organic elements have weathered. Freezing the swamp ore hastens this process greatly. The decomposition usually takes place more quickly when the content in organic substances is higher. Brown colored swamp ore (rich in humus) is usually decomposed in a year; on the other hand, the light colored (which is poor in humus), only after 2 to 4 years.

[1] C. A. Weber Ueber die Vegetation und Entstehung des Hochmoors von Augstumal im Memeldelta, etc. Berlin. Paul Parey, 1902, pp. 40 ff.
[2] Loc. cit. p. 47.

Poisoning of the Soil by Metallic Sulfur.

In considering factors injurious to plant growth ***ferric sulfid*** as ***pyrites*** (and rhomboidally crystallized as ***markasit***) must be noticed primarily since it is one of the most widespread precipitates produced in the formation of moors. Ferric sulfid is found less in moors themselves than in the underlying sand and on the line between the organic deposits and the subsoil. If pyrites weathers, there is produced by oxidation and absorption of water sulfuric ferrous oxid,—ferrous sulfate, *copperas*, and *free sulfuric acid* ($FeS_2 + 7O + H_2O = FeSo_4 + H_2SO_4$).

The ferrous sulfate oxidizes with the formation of basic salts to ferric oxid. In the presence of sufficient amounts of calcium carbonate, calcium sulfate (gypsum) is produced. If ferrous carbonate occurs, it passes over into ferric oxid or ferric hydrate with the loss of carbon dioxid and the taking up of oxygen. As is well known, the ferric hydrates cause the yellow to brown color of the soils and are able to absorb gases (carbon dioxid, nitrogen, etc.) to a very marked degree. Among them is the brown clay iron ore (limonite $Fe_2[OH]_6$) which cements together the surrounding sand[1]. In moor regions, however, the layers containing pyrites are often not oxidized at all; because of the presence of water and the strongly reducing action of the moor substance they cannot obtain any oxygen.

The most disasterous effect of the iron sulfid is its inhibition of the combining of the bases present in the soil and the free sulfuric acid formed by weathering. As a rule, calcium carbonate is present in the soil, so that gypsum can be formed, often alum or magnesium sulfate are also produced. An excess of the last can act injuriously. When experimenting with an excessive supply of alum, I found spotted necrosis appearing in barley. However, if the bases are absent, the free sulfuric acid will act directly as a plant poison.

If, in improving the soil, the layer containing the pyrites is brought to the surface, the soil will at first remain infertile.

Minssen[2] shows that at times the upper layers of the moor also contain iron sulfid. In a sample from Silesia he found 7.286 per cent. of the dry substance of the surface soil to be sulfuric acid, soluble in water, 3.940 per cent. ferrous sulfate and 3.346 per cent. free sulfuric acid and approximately twice as much in the deeper layers, aside from great masses of still unweathered iron bisulfid. The top of the sulfate here analyzed was later removed 62 cm. deep, so that the lower layers richly impregnated with iron sulfid were laid bare. The oxidation of the pyrites gave such large amounts of compounds injurious to vegetation that any agricultural use of the moor within a conceivable time seemed impossible. Such a case shows the necessity for the use of foresight in opening up lowland moors.

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1 Ramann, Bodenkunde, 1905, p. 87.

2 Mitteilungen d. Ver. z. Förderung der Moorkultur im Deutsch. Reich, 1904. No. 1.

The question as to the injuriousness of the ***black colored water flowing on to the meadows from the alder bogs*** of forests has been treated in detail by Klien[1]. In one especial case which gave rise to complaints against the forestry commission, the water coming from the forest was viscid, brown and at times smelled bad. In 100,000 parts, it contained 31.28 parts organic substances (humic acids, etc.) and 17.59 parts mineral substances, among others 7.81 parts calcareous earth, 3.07 parts ferric oxid, etc. The humic acids formed the injurious factor here. In similar cases it depends on the kind of soil overflowed by such bog water. It will be especially injurious if it flows over ferruginous soils or those with a clay subsoil, while a soil rich in lime can more easily withstand overflowing from the alder swamp, such as occurs in spring floods, because of the hastened decomposition of the humus, peculiar to such a soil. Nevertheless such water should be avoided for irrigation and back water.

The formation of ***ferruginous sand*** depends on the precipitation of ferric hydrate and iron silicates. Mixtures of ferric hydrates with varying amounts of ferric silicates and phosphates also give the so-called ***meadow-ore***. This combination occurs in moors, standing bodies of water and other places, where water containing iron comes in contact with the air, together with the co-operation of bacteria (iron bacteria according to Winogradski)[2]. One is inclined of late to lay stress on the co-operation of the micro-organisms[3].

Susceptibility to Frost of Moor Vegetation.

In moor soils which have been brought under cultivation, their especial sensitiveness to frost as compared with other kinds of soil has been proved by repeated experiments. In this, important differences are found if the moor soil has a sandy covering or if it is mixed with sand. Wollny[4] found in his experiments that the latter is more fertile than the former, in which the ground water was higher. Instead of the sand, a covering with clay has also been proved to be beneficial. In meadow cultivation when too much water has been removed, Fleischer[5] recommends covering with sand, rich in feldspar, or loam, or clay to avoid too great drying out. Jungner[6] gives further examples from the province of Posen. In them moor fields which had not been covered with soil containing clay, showed also a second total freez-

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1 Klien, Die nachteilige Einwirkung des aus Eller-Brüchen und Torfmooren kommenden schwarzen Wassers auf die Wiesen. Königsberger land- und forstwirtschaftliche Zeitung 1879, No. 28; cit. in Biedermann's Centralbl. f. Agrik-Chemie, 1880, p. 568.

2 Winogradski, Ueber Eisenbakterien. Bot. Zeit. 1888, p. 260.

3 E. Roth, Die Moore der Schweiz, unter Berücksichtigung der gesamten Moorfrage. Leopoldina, 1905, No. 3, p. 34.

4 Wollny, Untersuchungen über die Beeinflussung der physikalischen Eigenschaften des Moorbodens durch Mischung und Bedeckung mit Sand. II. Mitteil. Forsch. a. d. Geb. d. Agrik.-Physik. 20, 1897-1898, p. 187.

5 Fleischer, M., Ueber die zweckmäfsige Behandlung von Moorwiesen; cit. Biederm. Centralbl. f. Agrik.-Chemie, 1888, p. 137.

6 Zweiter Jahresber. d. Sond.-Aussch. f. Pflanzenschutz für 1904. Arbeit. d. Deutsch. Landw.-Ges. Part 107, Berlin, 1905, p. 61.

ing back of potatoes and pasturage, while those which had been covered had suffered no especial injury.

This discovery indicates that we have to look for the chief period of injury in spring, so far as frost phenomena in moor soils are concerned. In cultivating trees this becomes clear, if we consider that the humus soils in cold seasons usually contain an excess of moisture. The fine pored humus, saturated with water, will cool more slowly in the fall than do soils less rich in water, but will warm up much more slowly in the spring. However, the longer the roots are in a warm location, the longer they remain active and the more water will be forced up into the aërial axes. Trees growing poorly on moor soil with its diluted nutrient solutions start the winter with a large water content in their tissues. The more water the tissues contain and the less cytoplasm, the more susceptible are they to frost, no matter whether the effects of winter or spring frosts are concerned. Hence the frequent and great injury from frost in moor pines, as is shown in the example from the Lüneburger moor.

For short-lived field plants the most disasterous are the spring frosts which are produced in rays of cold. This may be easily recognized from the fact that the phenomena of discoloration produced on the leaves and stems by the cold are abruptly cut off, if such a part of the plant is partially covered by overlying leaves.

It is now pertinent to ask when cold, due to radiation, will be greatest and how much of it is due to evaporation. If both factors become effective to a high degree, the air layers close above the surface of the soil will be noticeably colder than the average temperature. Polis[1] has proved such a lowering of the temperature of the air layers above a covering of snow. This will be the greater, the less the movement of the air. Hence May frosts in still, clear nights. The moor soils and those bordering on moors with their wealth of water will evaporate strongly in the early spring when the soil and subsoil have not been warmed through, even if, as cultivated land, they have been mixed with sand and accordingly more cooled down. Evaporation will also be still more increased by the dark color of the soil, as Wollny's[2] experiments show. Covering with a layer of sand from 6 to 10 cm. deep acts as a preventive. Then but little water can reach the sand from the humus layer and, correspondingly, only small amounts will be evaporated. For the same reason *the dead layer also acts as a protection against drought.* One disadvantage of the sand covering is found when fine, surface-rooting grasses are sown which are easily stunted in sand, poor in nutrition[3].

If the cultivation of fruit trees on moor soils is involved, the following may be recommended for protection against frost: (1) The planting of trees on the west and southwest side of the orchard, in order to modify the temperature differences in spring. The bark cracks almost without ex-

[1] Meteorologische Zeitschr. 1896, Part I.
[2] Blätter für Zuckerrübenbau, 1899, No. 9.
[3] Mitteil. d. Ver. z. Förd. d. Moorkultur, 1895, Nos. 5 and 6.

ception on the sides turned towards these points of the compass and the normal phenomena of loosening bark scales (for example, on plane trees) also begin earlier and to a greater extent on those sides of the trees. (2) A strong liming and supply of Thomas slag with a sufficient provision of other nutritive substances. (3) Above all, however, those varieties of fruit should be chosen, which endure moor soil. Huntemann[1] recommends the common house plum, from practical experience. Of apples, the following have stood the test: Bosbook's Beauty, Golden noble, Double pigeon, White winter apple, Orleans, Parkers Pippin, Purple red Cousinot. The winter Yellow Pearmain, Gravenstein, Prince and Alant apple should not be planted, since they are too susceptible to frost and also to canker. According to the experiences of Mr. Klitzing, a nurseryman, the following apple varieties are adapted to cultivation on moor soils,—red Eiser apple, Burchardt's Reinette, and Cludius' Autumn apple. Of pears, he recommends Charneux Delicious, St. Germain and New Poiteau. If cherries are tried at all, sour varieties should be chosen rather than sweet ones.

THE USEFULNESS OF THE SPRUCE.

In considering forest plantations on moist soil, we only reiterate our opinion that it is a mistake to plant pines so extensively as is now done. The example cited on p. 248 from the Lüneburger moor shows clearly enough what disadvantages arise. If they are not so distinctly noticeable in other places and especially if frost injuries do not appear so sharply, yet a weakened growth is always induced, which sooner or later becomes evident.

For the plains in northern Germany we should return to the spruce. We use the term "return," for Conwentz[2] has actually proved that often, in moor regions, spruce was the original covering. Even now in Pomerania and Hanover, even on the Lüneburger moor, original spruce woods are often still in existence, and the various cases especially studied by Conwentz give excellent indication that the spruce is still found in a developmental stage, resembling the primeval forests, on soils where wide stretches are covered with peat moss and the moisture in usual years makes access to the soil impossible.

This opportunity should be taken to consider the *layering formations* of spruces, which at any rate may be found only in forests not touched by forestration and it is advisable on this account to preserve accounts of especially good examples of increase by means of *layering*. Hence an illustration and description of a spruce family should be given here, which has been observed in the vicinity of the city Kragerö on the south eastern coast of Norway (see Fig. 33). Schübeler[3] describes it as follows. The parent trunk, which stands at the foot of a hill, had a height of approximately 9.4 m. and, about

[1] Huntemann, Das Erkranken der Obstbäume auf Moorboden. Mitt. d. Ver. z. Förd. d. Moorkultur. 1898, No. 7.
[2] Conwentz, H., Die Fichte im norddeutschen Flachland. Berichte d. Deutsch. Bot. Gesellschaft 1905, Part 5, p. 220.
[3] Schübeler, F. C., Die Pflanzenwelt Norwegens. Christiania 1873-75, p. 164.

6.6 cm. from the ground, a circumference of 94 cm. At a height of 31 to 36 cm. three branches left the main trunk, and took root in several places. At a distance of 1.6 to 2.5 m. from the present trunk, six regular spruces have gradually developed with a height of 2.5 to 4.7 m.

Fig. 83. A spruce family produced by natural layering. Three of the branches at the base of the trunk have rooted again in several places and their buds have there developed into secondary trunks. (After Schübeler.)

The spruce stands by itself in its easy formation of adventitious buds, giving rise to gnarls, and in the ability of parts of its aërial axis to form roots quickly. To be sure Schübeler (loc. cit. p. 163) has also observed rooting in low branches of Juniperus and also in *Taxus baccata*, which have been bent to the earth, and certainly such conditions will occur also in other conifers which grow well from cuttings. But cases of this kind will always remain isolated.

The capacity for increase, explained here by means of the one example, has a greater significance in moor regions, where the spruce will have to be grown as the only possible means of forestration.

Only very few varieties of conifers possess this facility for forming layers and developing new regular top growth from lateral sprouts. Gardeners make abundant use of this peculiarity in propagating young individuals from cuttings. In other conifers, cuttings from the lateral branches retain the structure of laterals and do not form handsome trunks. The

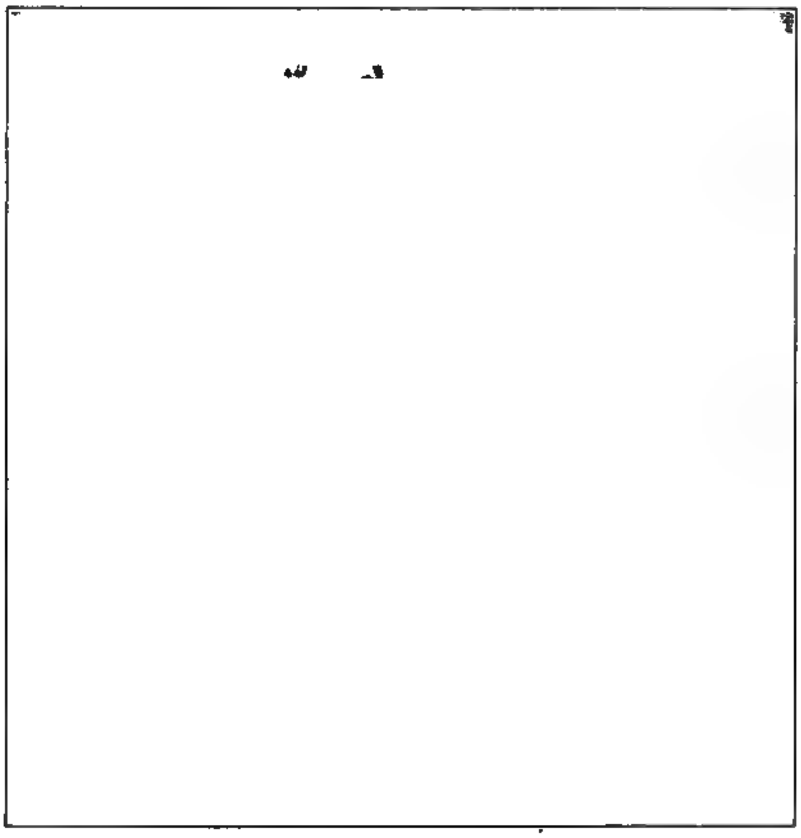

Fig. 34. Oak from Rogau (Upper Silesia) with a formation of sinkers. (Orig.)

genus Araucaria also has a great tendency to form head shoots and this is often shown in individual lateral branches, which remain on the parent plant, when the top shoot has been lost.

In connection with this layering formation of the spruce, occurring on damp soils, we give in figure 34 the sketch of a case of root formation from a branch of an oak, which has been observed only once. In the 80's of the last century, I had an opportunity in the castle park at Rogau (Upper Silesia) of seeing the very hollow trunk of an old oak which stood on a low lying meadow, liable to be overflowed by the Oder at flood time. The tree

had already lost most of its leaves on the lower branches. The upper parts of the two lowest branches, probably at some time bent down intentionally, lay deep in the earth, but their tips had been turned upward. At the point where the branch was bent (at the right in the figure) a strong root was traceable which might have been produced when the still young branch tip was covered with silt by the first floods. The increased nutrition, produced by this root, showed itself in the development of a considerable number of younger shoots, resembling an independent bushy growth. I noticed nothing especial in the vigorous spruce plantations standing at some distance.

Changes in Moor Soil Through Cultivation.

One must determine finally how far the injurious factors of humus soil show in cultivation and what changes it undergoes with cultivation. *"Sanding"* has been discussed already. ***Fertilizing*** comes next under consideration, since the nutriment content especially in highland moors is so scanty that only plants needing little nutriment and highly resistant to humic acids thrive there (Sphagnum, Eriphorum, many Carex varieties, Calluna, etc.). All fertilizers must act, first of all, by increasing those microorganisms which can decompose the soil, since in soils containing humic acid, the ***bacterial*** flora is very scanty. Fabricius and v. Feilitzen[1] gained much information on the methods to be used in increasing the bacterial flora of moor soils. Stålström[2] had already determined that draining the water from moor soil, very poor in bacteria, naturally will increase the number of organisms. This is especially significant for highland moors, since they have not nearly as many bacteria as the lowland moors;— a fact related to the scanty nitrogen content of the highlands. Moor soil mixed, with clay or improved by fertilizing, has a higher bacterial content. The bacterial flora remains almost exclusively in the upper soil layer, 15 to 25 cm. thick. Fabricius and v. Feilitzen also tested the moisture content in the upper soil layer and found that, in uncultivated highland moors, this fell only from 90 to 87 per cent. by draining, while, on the other hand, it could fall to about 64 per cent. with other cultural measures. These consisted in mixing the friable soil with sand, with the result that vegetation of a different character developed. The soil temperature was lowest on the virgin moor. Simple draining exerted but little influence (+0.3°C.), but cultivation gave a permanent increase of almost 2°C. In regard to the chemical composition, it was found, as was to be expected, that the calcium content was very small in natural highland moors and the nitrogen content equally scanty, while in the lowland moors the latter was found to be satisfactory. The disappearance of the humic acids through cultivation is very interesting. In the

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[1] Fabricus, O., and Hjalmar von Feilitzen. Ueber den Gehalt an Bakterien in jungfräulichem und kultiviertem Hochmoorboden auf dem Versuchsfelde des Schwedischen Moorkulturvereins bei Flahult. Centralbl. f. Bakteriologie etc. II Section, Vol. XIV, p. 161. 1905.

[2] Om lerslagningens betydelse. Finska Mosskulturföreningens årsbok. 1898. p. 44.

natural highland moor the content amounted to more than 2 per cent. and through sanding, liming, and fertilizing became reduced to possibly 0.3 per cent.

These same investigators found the bacterial flora only sparsely developed, as a result of the acid soil in the highland moor, and also but little increased by draining. On the other hand, a great increase was found after sanding, liming and fertilizing together with the necessary attendant working of the soil. Sand introduced new bacteria, stable manure furnished rich nutriment of such a kind that the bacterial content become as great as in a lowland moor under the same cultural conditions. In both the bacterial content increases and falls directly with the soil temperature.

The experiences of practical workers disagree greatly as to the use of stable manure. In many places there has been failure. But, on the other hand, reports are found, which determine a very beneficial effect from stable manure even on moors with a large nitrogen content, as Count Schwerin reports[1].

This contradiction can be explained as follows. Even in moors, which contain nitrogen in excess, fertilizing with stable manure can act very beneficially if the moor is but little decomposed, the nitrogen in it therefore being probably still in a form not easily taken up (for example in organic compounds). On cultivated moors, however, the yields after fertilization with manure are actually poor and the weeds grow in excessive quantities because an excess of nitrogen probably makes itself felt, due to the addition of manure without the sufficient counterbalance of a phosphate and calcium supply.

Potassium is a factor primarily involved in the cultivation of moors. This holds good also for moor-meadows, on which, however, a good hay harvest, according to M. Fleicher[2], requires the addition of phosphoric acid (Thomas slag) besides potassium. (In this connection, he warns against over-fertilizing if the *ground water* level does not lie deeper than 20 to 40 cm.). The form in which the potassium is given may also be determinative in the majority of cases, for Tacke[3] obtained the best results for potatoes with *potassium chlorid.* While the tubers contained 17.67 per cent. starch without fertilizing and 17.02 per cent. when fertilized with kainit, and only 16.48 per cent. with karnallite, they contained 18.02 per cent. with the addition of potassium chlorid. The fertilizers were added in the fall; spring fertilizing reduced the quantity and quality of the tubers. Hensele[4] found in his potato cultural experiments that kainit on meadow moor soils considerably repressed the starch content of the potatoes. In comparative cultures on mineral and moor soils, the yields from the former were larger and the starch content of the moor potatoes never equaled that of the tubers from a mineral soil or that of the seed.

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1 Mitt. d. Ver. z. Förd. d. Moorkultur, 1895, Part 6.
2 Milchzeitung 1887, No. 8.
3 Mitt. d. Ver. z. Förd d. Moorkulture 1895, No. 6.
4 Hensele, J. A., Bericht der Moorkulturstation, "Erdinger Moos," 1900-01. Centralbl. f. Agrik.-Chemie, 1903, Part 3.

In regard to the injuriousness of *spring fertilizing,* reference should be made to the reports of the General Assembly of the Society for the Advancement of the Cultivation of Moors[1]. Here it is especially emphasized, that kainit and Thomas slag must be scattered in the fall because spring fertilizing reduces the sugar and starch content in vegetables which require hoeing. For Thomas slag, the fall fertilizing is said also to be more beneficial because the acid of the moor can then act as a solvent for a longer time. Chili saltpetre in cultural experiments had decreased the sugar content in edible roots about 1.5 per cent. The preceding crop also seems to have an influence on moor cultures, as is shown by a case from the province of Posen[2]. There sugar and late grown fodder beets became diseased when grown after mustard. In regard to beet cultivation, Hollrung[3] arrives at the conclusion that pure moor land should be avoided entirely and even that which has been sanded should be used only with care.

Rotten Bark.

Up to this point we have learned to recognize the characteristic starved types of growth on acid moor soil; these are due not only to the scarcity of nutriment but to moisture conditions as well, either a lack of water arising from the fluctuations in the subsoil, or an excess. These manifest themselves in older trees by a greater formation of bark, when high cushions of heather and moss surround the base of the trunk. These dense cushions store up water, in part retaining that of the moor soil, in part collecting that of the atmosphere, and in this way forming a moist felt constantly growing up higher around the base of the trunk. Such damp cushions decrease the temperature variations necessary for the pushing off of the old bark scales. However, they hinder the supply of air especially and cause the decomposition of those cell layers in the bark scales, which are especially loosely constructed, into a deep brown mass, powdery in a dry condition and slimy when very damp, which is called *"rotted bark."* In these are found the brooding places of many animal and vegetable organisms which carry on and hasten decomposition.

An investigation of the younger layers under the old bark scales throws light on the production of these rotted masses. One of the pieces of bark furnished by Dr. Graebner from the Lüneburger moor was 3.5 cm. thick and differed from equally old, healthy bark in that it could be peeled with unusual ease into separate layers varying in thickness. The upper surface of the different bark layers, as they fell apart, was rough like a relief map and covered in places with hard, woody processes in the form of broad cones up to 2.5 mm. high and often with crater-like depressions. Such processes, just

[1] Berichte der Generalversammlung des Vereins zur Förderung der Moorkultur Jahrg. 1895, p. 123.

[2] Elfter Jahresber. d. Sonderausschusses f. Pflanzenschutz. Arb. d. Deutsch. Landw. Ges. Part 71, p. 130.

[3] Hollrung, Die verschiedenen Bodenarten und ihre Eignung für den Rübenbau. Blätter f. Zuckerrübenbau, 1905, No. 14, p. 217.

like the tissue cushions on the various deciduous bark layers, which are like warts and occur in lines, were found always on the inner side of the layer which was being raised up and had exactly the appearance pictured later under the section *"Bark Refuse"* in the elm. This section should be consulted.

The greatest possibility of separation of the lamellae from one another was found where a rotted tissue layer, i. e., in a condition of humifaction, began to disintegrate and formed a surface of separation. The rotted bark consisted of cork cells, as shown on the upper side *B* in the accompanying cross-section (Fig. 35), while *H* shows the bark which lay nearer the wood, and

Fig. 35. Mouldy bark scale of a pine from the Lüneburger moor. (Orig.)

therefore was younger; *rp* is corked, firm bark parenchyma while *k* is the full cork, loose bark parenchyma and *t* the plate cork. The bark scales were therefore composed of bark parenchyma elements, which advance further and further toward the fresh bark and the cambium. They are separated by layers of sheet cork and become suberized. Besides this, we also find clusters of loose cells, which are more abundant the deeper the base of the trunk has stood in the moss. The spongy constitution of the underside of the different bark lamellae arises from the morbid luxuriousness of the parenchyma and full-cork masses. As a result of the moisture and the scanty supply of oxygen, these excrescence tissues become slimy and form the rotted bark, which facilitates the separation of the lamellae.

The great part which the bark parenchyma, with its abnormal phenomena of stretching, plays in the formation of the bark shows that this development of rotten bark in the moor pine is related to the *"bark refuse"* of the elm and distinguishes both cases from the actual tan disease (see page 215) in which the formation of full cork has the upper hand, as in the many-layered lenticels.

Horticultural Moor Plants.

The growers, probably because of their study of the natural habitat of our heather plants, have used for imported Ericaceae the soil in which our Calluna grows splendidly:—i. e., heath moor. The properties of Sphagnum peat, thus ascertained, have made this a desired article in trade. Its advantages consist in its loosening properties. The results of experiments in cultivating Ericaceae led to the mixing of the so-called moor soil with heavier nutritious soils as a loosening substance. In this way, the moor soil has been introduced as a necessary element in soil mixtures for most of the finer horticultural plants. Since no standard was known, however, for a good moor soil, many kinds came into trade, with the growing demand. Some were either over rich in raw humus, or resembled the character of the *meadow moor.* The dark color of the meadow moor led to the incorrect opinion that a very nutritive earth was present. The results of this misconception were very evident. The complaints of gardeners about acid heath soils are almost universal and the degeneration of many favorite plants, such as the so-called new Holland, or "Cape plants," could not be arrested.

Where meadow moor was used as an admixture in soils for potted plants, its properties quickly manifested themselves. In a dry condition, this moor soil seems to be easily pulverized, decomposing into a powder, or remaining crusty. When wet, however, it becomes smeary and cements the other particles of soil into dense masses with a poor air content. Since meadow moor heats greatly, the upper layers in the flower pot dry out easily, become lighter colored and suggest to the gardener that the whole ball of soil is dry and should be watered. Here is the danger, for meadow moor deceives as does no other soil. If such moors be investigated in nature, the smeary condition is found directly under the dusty surface, a few centimetres deep, since the very binding substance retains the water unusually long. Potted plants are often killed by a lack of oxygen at the roots, even if the humic acids are not taken into consideration. These, however, play a disasterous *rôle* and often cause the injury arising in many cases from the use of loose, fibrous marsh soil. Sphagnum peat is the most beneficial because the leaf is so constructed that it makes a very porous soil, giving rapid moistening and as rapid an aëration of the soil in the pot. The excellent results obtained in growing orchids with sphagnum are well known. Good results will only be had with fibrous moor soils, full of fragments of Vaccinium and other moor plants and taken from forest soils, if the raw humus is

removed and the decomposed layers used; even an admixture of lime, or still better, of calcium phosphate is advisable.

I have mentioned the poor growth of plants in moor earth in a special section, because I am of the opinion that a very considerable number of phenomena of disease may be traced to the acids in the soil,—the gardener says that the soil smells sour. Even those specific plants, such as Rhododendron, Azalea, etc., only thrive when, as in their natural habitat, they stand in fibrous earth which is easily aërated. In the moment when a mixture of moor soil with more nutritive solid soils is used for potted plants, we find root-decay, which is indicated by the brown edges of the leaves. I consider the theory of the necessity of an admixture of moor soil in cultivating the majority of our finer potted plants to be erroneous. As far as my experience goes, ***sand*** can give incomparably better results as a loosening material. The gardener should work with well decomposed leaf mould or compost earths and add large amounts of sand. If care also is taken to have good pot drainage, there will not be so many complaints about root diseases in the future.

Specking of Orchids.

A special illustration of the advantages of the use of sphagnum, described in the previous division, is found in the peculiar black spotted condition of the leaves of epiphytic orchids. In our green houses there are many leaf diseases which frequently arise from fungus infection (Gloeosporium and Colletotrichum, Phoma, Phyllosticta, etc.). We find many cases however, in which fungi take no part or occur only secondarily and among these an infection should be emphasized especially which may be found in Cattleya, Laelia, Dendrobium and the members of the group of the Vandeae.

The course of the disease is explained best by the description of a special case, which, occurring in *Phalaenopsis amabilis* var. *Rimenstadiana*[1], has recently been studied more closely. All except the youngest leaves of plants grown in leaf mould in pierced pots and watered with tap water were spotted yellow to black. The disease advanced apparently from the older to the younger leaves and manifested itself, in its early stages, by the appearance of irregularly round or oval, pale, translucent spots. These were scattered over the whole leaf, but usually appeared first and most abundantly at the tip. When such leaves were cut off and lost water by evaporation, the spots which became pale at the beginning of the attack, could be felt like warts over the healthy leaf. These conditions changed, however, as the disease advanced, since the yellow spots at once took on a whitish appearance and were depressed like saucers. In this it was seen that different adjacent centres of disease coalesced, forming connected, thin surfaces, which finally turned a deep blackish brown and were enclosed like a wall by the healthy tissue. After turning brown, however, the spots ***did not increase in size***

[1] Sorauer, Erkrankung von **Phalaenopsis amabilis.** Zeitschr. f. Pflanzenkrankh., 1904, Part V.

There were also centres of disease, which remained restricted to definite groups of tissues.

When one of the browned spots, covered with longitudinal bands due to the darker veining, was cut through, it was found that its paper-like consistency was not produced by a possible atrophy of the tissues, resulting from an injury due to insects, or from bacteriosis, but only by the drying together of the mesophyll cells, which have been almost entirely depleted of their contents. The boundary between the dead and the wall-like convex bordering healthy tissue was sharp, with no transitions. The collapsed brown or (mostly) light walled tissue when treated with iodine, showed only isolated flakes of cytoplasmic contents together with little drops of a colorless or golden-yellow substance. With the entrance of water, the cell walls, like the folds of an accordion, were raised somewhat from one another, without the cells having been brought to their previous size. In the absolutely dead tissue isolated, colorless, slender mycelial threads were found at times.

If glycerine was allowed to act on the fresh sections, which, moreover, also gives a strong acid reaction at the diseased spots and shows no oxydases and peroxydases with guaiak and hydrogen peroxid, large, irregular or usually spherical masses were drawn together in the cell contents. This phenomenon was often found in especially sappy tissue, rich in sugar. At the periphery of these masses lay the chloroplasts. In the badly diseased parts these groups of substances could not be found at all, but only numerous very small or somewhat larger drops. Just as little can this contraction of the cell contents into strongly refractive drops be proved in the healthy part of the leaf. We might place it in the list of glucoses because, with the Trommer test, they show in places precipitates of cuprous oxid.

Further anatomical investigations led to the discovery that, in the various yellowish tissue centres, the cell content was used up too strongly, and the mesophyll cells had grown out wider. The diseased place thus became somewhat swollen up over the healthy surface, but at once the diseased tissue, which had lived out its life very rapidly, showed this by the appearance of carotin drops; it collapsed, turned brown, and dried up. This process of drying, however, is limited, in all cases observed as yet, to the *leaf region characterized in the beginning by the turning yellow.* In this the phenomenon is distinguished from fungous infections. Since now enormously increased formation of sugar can be proved and the absence of parasites determined in the majority of spots, we have under consideration a constitutional disease which set in, where the *orchids named were cultivated in leaf mould.*

This cultural method has been especially recommended in the last few years by Belgian and English gardeners and introduced into Germany in part with the use of Flemish leaf mould. After the rapid spread of the disease, the old process of growing the plants in a mixture of sphagnum with bits of moor soil was again followed and the earlier results were again ob-

tained. From this it is evident that leaf mould, an extremely favorable substratum for most other plants and in which the orchids named at first grow very well, gradually becomes slimy when copiously watered (especially with water containing algae) and does not let the necessary supply of oxygen reach the roots of the orchids.

Much better results have been obtained with the so-called *Jadoo fibre*, a very porous moss peat saturated with nutritive salts. Yet the result does not justify the increased expense and the old sphagnum culture always proves to be the most advantageous. The modern endeavor of growers to force the orchids to an earlier and more luxuriant development by abundantly supplying nutritive substances, high temperatures and great moisture, gives actual good results only for a limited time. Usually a reaction sets in in the over-stimulated plants, which can be prevented only by a dormant period in a relatively cooler, drier place.

Cooler, drier sand is also in many cases the best protection against decay from fungus. Klitzing observed a very instructive example in a spot disease of *Vanda coerulea*, called forth by Gloeosporium which is now pretty universal on the continent and in England, as well as even in our country. The statements of the collectors show that this Vanda is found in the Himalayas on Gordonia, which grows in moderately warm, *windy* habitats. Here, in our conservatories, the plants are cultivated, on an average, more than 10°C. warmer and kept year in and year out in closed, moist greenhouse air. Naturally the plants become more tender on this account and succumb within a few days when artificially infected with Gloeosporium, while, in their native habitat, the fungus is restricted and the plants develop further and increase, despite its presence.

CHAPTER III.

UNFAVORABLE CHEMICAL SOIL CONSTITUTION.

I. Relation of the Food Stuffs to the Soil Structure.

A. Soil Absorption Resulting from Chemico-physical Processes.

Injuries to vegetation can take place either because the capital of nutritive substances in the soil takes a form quantitatively or qualitatively unfavorable for the nutrition of the plants, or because, with an abundant supply and normal composition of the nutritive substances, the plant's capacity for taking them up will be arrested by other factors of growth. Thus, either a lack or an excess of the nutritive substances can make itself felt, or, because of modified conditions of absorption, one single nutritive substance can be present in amounts too scanty or too great for effectiveness, and thus disturb the equilibrium in the organism. This second form of nutritive disturbance will be treated in the following division under the headings, "Lack of moisture and nutritive substances" and "Excess of moisture and nutritive substances."

The consideration of the supply of water in this connection, together with nutritive substances, is justified by the fact that the water not only furnishes these by its decomposition in the plant body, but also, as a transporting medium, causes weak or strong concentrations of the nutrient solutions according to the amount of water present, thus influencing beneficially or disadvantageously the process of nutrition. In view of the constantly changing concentrations, the influence of the water will therefore have to be taken into consideration, when studying the relation of the nutritive substances to the soil structure.

The soluble salts produced by the decomposition of the minerals or introduced by fertilization, serve as a basis for soil absorption. The retention and giving up of the salts, as also their transformations continually taking place in the soil, were thought at first to be predominantly physical processes, while they now, in substance, are considered chemical processes[1]. In any

[1] See Ramann, Bodenkunde, 2nd. Edition, p. 21, Berlin, 1905, Jul. Springer. In the remainder of this section, if other authors are not cited, we rely chiefly on the work here named.

case, it is difficult to draw a line between physical combination (absorption) and chemical combination. •

Absorption becomes of importance, only where large absorptive surfaces are offered, as in organic substances and certain inorganic ones, to which belong the colloidal silicic acid and the colloidal ferric oxid of the tropical red soils. Those humus substances, capable of being swollen, seem of the greatest significance which are precipitated in soils rich in nutritive substances, such as salt-like compounds, but remain to a great part in solution in impoverished soils. In the absorption of humus substances the first *rôle* is played by their capacity to take up free bases and their carbonates. The acid humus substances are especially effective for the ammonia found in the soil and for ammonium carbonate and we take advantage of this fact especially when using a *peat mulch.*

Besides colloidal substances, the finely distributed mineral elements should be kept in view as a means of absorption. Of the minerals, however, quartz always and kaolin, when not combined with alkali silicates to form the absorptive double silicate, have no capacity for absorption. The chief bearers are the hydrated silicates, especially the double silicates of aluminum, which, crystallized as *zeolites,* are found in rocks, and also those of ferric oxid. They make possible the exchange of bases observable in the soil.

This becomes effective with the *exhaustion* of the soluble nutritive substances in the soil as is made clear by the following experiment carried out by Lomberg[1]. A hydrated silicate was kept for three weeks in contact with water containing carbon dioxid, and, after some time, the following composition was found:—

	I. Original silicate.	II. After treatment with water containing carbon dioxid.
Silicic acid	46.64 per cent.	54.03 per cent.
Aluminum oxid	29.38 " "	39.65 " "
Potassium	22.75 " "	5.34 " "
Sodium	1.83 " "	0.00 " "

If this leached silicate II. was again treated with a solution of caustic potash, the following composition was found,—silicic acid, 46.60 per cent.; aluminum oxid, 35.67 per cent.; potassium, 17.73 per cent. Therefore, in the silicate skelton, the greatest part of the potassium had been taken up again, so that a new condition of chemical equilibrium had been set up.

If ammonium chloride was added to the original silicate I, the reaction resulted in,—silicic acid, 56.17 per cent.; aluminum oxid, 34.59 per cent.; potassium, 0.89 per cent.; ammonia (NH_3) 8.37 per cent. If a very large excess of calcium salts had been present, instead of the ammonia, the calcium could have replaced the potassium entirely in the silicate, as has act-

[1] Zeitschr. d. Geol. Ges. 1876, p. 318..

ually been shown by Rümpler's experiments and later those of Schlöszing Such processes are constantly present and show how quickly a soil can be leached by continued abundant precipitation, or can be impoverished in the supply of its other valuable food stuffs by a one-sided supply of fertilizer.

The addition of fertilizer and the consequent increase of nutriment does not always give the expected increase in the yield. This occurs especially in rich soils and is explained by the fact that such a soil is no longer in a condition to absorb, as a direct result of its wealth of nutriment. Soils poor in clay are especially able to cause such phenomena because of their small absorptive power.

A further painful surprise, connected with absorption, is the *poisoning of the soil* from metallic salts. All heavy metals combine actively and, on this account, for example, the failure of crops, observable near smelting works, may not always be ascribed to the sulfuric acid of the fuel alone, but often also to the larger accumulations of metallic compounds. The fact, as shown by experience, that plants will live in soil containing small quantities of copper, lead, zinc, etc., has, up to the present, prevented paying the necessary attention to this kind of soil poisoning.

With potassium and ammonium, both of which combine actively, absorption often takes place by exchange in equivalent amounts (3 parts K_2O for 1 part NH_3), whereby sodium, calcium and magnesia pass over into solution. The easily dissolved, salt-forming sodium is only weakly absorbed and, to a still lesser degree, the calcium, present in the form of its humate, carbonate or phosphate, which can easily be replaced in the silicates by other bases. Magnesium acts similarly. Acids are combined only when they form insoluble salts. This is especially the case with phosphoric acid, which forms insoluble compounds with calcium, magnesium, ferruginous earth and aluminum oxid. Sulfuric acid is very weakly absorbed, nitric acid and chlorin not at all. The latter case deserves consideration in the chlorin poisoning near hydrochloric acid factories.

By the different absorptive capacity and the constant exchange of nutritive substances is explained the *effect of many fertilizers* which have a two-fold action,—disintegrating and thereby increasing nutriment and exhausting the supplies. Thus an abundant supply of potassium salts and Chili saltpetre exhausts the calcium and magnesium in the soils. The expression, "soil impoverished from marling" indicates that marl, as well as gypsum, can prematurely exhaust the nutritive stores in the soil by a disintegrating action. In this disintegration lies also the value of *sodium chlorid* (common salt). A greater source of poor production is found in the acid content, especially in the abundance of humic acids which greatly weaken the absorption and are in a condition to dissolve all the elements in the soil. This subject has been treated more thoroughly under the disadvantages of moor soils and under the formation of swamp ore.

The less the various nutritive substances are retained and the more soluble their compounds, the more easily they are leached out. At best, they reach the deeper soil layers, and in regions of strong sudden precipitation, they can be carried away. The chlorids present in small amounts in most soils are most easily removed, then the nitrates, later the sulfates. This takes place slowly with carbonates of calcium and magnesia and the phosphates are the most persistent of all. Chlorids are dangerous for agriculture in regions of very slight precipitation, where they accumulate in low lying places, and produce highly concentrated soil solutions. Under the same conditions, the so-called *"alkali soils"* are produced by carbonates and sulfates.

The question of nitrogen is the most important. The nitrates are so very soluble that the upper soil layers, containing the superficial roots, can be leached of all their nitrates even if the subsoil contains abundant nitrogen. This can only be made available by means of deeply rooted plants. In the face of general practice, not enough emphasis can be laid on the great losses occurring with unsuitable fertilization of the fields. Of the calcium salts, gypsum must be considered since it contains sulfuric acid. With calcium carbonates in damp climates, even on soils made from disintegrated lime stone, the calcium content may be poor because the carbonate is slowly leached out[1]. On the other hand, all the potassium phosphates as well as the phosphoric compounds (with the exception of the alkalis) belong among the most persistent minerals. An exception takes place only in soils with free humic acids. Here the phosphates and also the iron compounds become soluble and even the resistant silicates are decomposed and carried over in a soluble form. In this way moor soils are exhausted of all their mineral elements, excepting quartz.

The natural process of enrichment of the soil by weathering and by the action of wind in moving soil masses, by the decay of organic substances, etc., which effectively counteract leaching, is of value only in long-lived plantations. Here the fact, that the deep growing roots get the nutritive substances from the subsoil, again made available for the upper soil layers by the falling of the leaves, is surely of great importance. In our plantations of one and two-year old plants, we find this help only in the use of *green manuring.*

Finally, soil impoverishment from *draining* must not be passed over. However useful this practice is, as already acknowledged under soil aëration, in places it can act most injuriously. This refers especially to the leaching of nitrates from the soil in localities, where the fertilizer cannot be extensively supplied. Naturally the loss reaches a significant amount where an abundant supply of nitrogen is present, as is shown, for example, in Lévy's analyses of the drain water from the Parisian sewage fields[2]. In a liter of

[1] (If water containing carbon dioxid comes in contact with calcium carbonate it forms calcium bicarbonate, which is much more soluble and passes off in the drainage waters. This always occurs in soils containing organic matter.—H. S. R.)

[2] Wollny, E., Die Zersetzung der organischen Stoffe, etc. Heidelberg 1897, p. 4.

the drainage liquid, as it flowed away, were contained 0.8 to 0.9 mg. of nitrogen in the form of ammonia and between 19.1 to 27.1 mg. of nitrogen in the form of saltpetre. The liquid sewage used for the irrigation contained 24.9 mg. ammonia nitrogen and 0.9 mg. saltpetre. A comparison of these figures shows that the fertilizing nitrogen introduced in the form of ammonia is oxidized almost entirely to nitric acid by bacterial action during its filtering through the soil. Way's investigations[1] show that, on an average, no very large amounts of mineral elements may be detected in drain water. He found in 1000 parts only 0.003 parts of potassium, 0.186 of calcium, 0.138 of sulfuric acid, 0.002 of phosphoric acid, etc. Nevertheless we should not forget that continued reductions are involved which are added to one another, in case there is abundant drainage.

A comprehensive summary of lysimeter experiments in Rothamsted, which covered 35 years, and more recent investigations in Holland[2] show how rapidly, as a rule, the nitrification of the fertilizers, such as the ammonia salts, takes place of itself. Even in the fall and winter the nitrification is so active, that great nitrogen losses may be expected. On this account it is advisable to *use ammonia salts as a top fertilizing* in the spring.

When using sulfates and chlorids of ammonia, the calcium combined with the sulfuric and hydrochloric acids is washed away in large quantities in the drain water. This process is necessarily preliminary to the combination of the ammonia in the soil and the subsequent nitrification. If the calcium carbonate does not suffice for this conversion, the ammonia salts easily become dangerous for the plants. Since the sulfates and chlorids of potassium, like those of ammonium, form gypsum and calcium chlorid, which are not absorbed by the soil, the necessity of a *periodic liming* is evident.

B. The Work of the Soil Organisms.

The activity of animal life in relation to the changes in the soil is mentioned in the third volume of this work. In this is concerned primarily the work of the soil bacteria, the agricultural significance of which has been shown in a very comprehensive short summary by Behrens[3] and Hiltner[4].

According to the chief work performed by the bacteria, we could speak of those which set free the nitrogen and others which attack the carbon compounds (as, for example, the pectin and cellulose ferments) and finally those forming humus and those decomposing it. But not only the action of these organisms on their substratum is of importance here, but, especially, their influence on each other. Some genera or species disintegrate one another, others nourish each other.

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[1] Further analyses by A. Mayer, Agrikulturchemie. 5th. Edition, 1902, Vol. 2, Section I, p. 118.

[2] Beleuchtung der Bodennitrifikation durch Drainwasseruntersuchungen. Mitteil. d. D. Landw. Ges. 1906, Stück 13.

[3] Behrens, Die durch Bakterien hervorgerufenen Vorgänge im Boden und Dünger. Arb. d. Deutsch. Landwirtsch.-Ges. 1901, Part 64.

[4] Hiltner, L., Ueber neuere Erfahrungen und Probleme auf dem Gebiete der Bodenbakteriologie etc. Arb. d. Deutsch. Landwirtsch.-Ges. 1904, Part 98.

The influence of *carbon disulfid* serves as an important example, for, besides a poisonous action, a stimulus directly beneficial to growth has been assumed for it. The latter is thought to be recognized in the fact that a clearly recognizable increase of fertility sets in after the disappearance of the carbon disulfid and its influences which arrest growth. Hiltner succeeded in proving that the carbon disulfid chiefly conditions the changing phenomenon by disturbing *the equilibrium of the bacterial flora of the soils.* By means of its ability for dissolving fats, it suddenly forces back the bacteria which had prevailed up to that time, just as it also stops entirely the increase of all species, so long as it is present unchanged in the soil. If the poison become diluted, or disappears through conversion, the long repressed numerical growth of the soil organisms increases in such a way, that, for example, an increase of 9 millions of the species growing on meat-pepton-gelatine to 50 millions in one gram of soil could be proved in one case. Thus an increase in the nitrogen production and with it of the potato harvest could be determined chemically by Moritz and Scherpe.

With reference to the behavior of the nitrogen bacteria described in the second volume[1] under soil bacteria, we will here only supplement the facts stated there. After Winogradski especially had proved the conversion of the ammoniacal nitrogen to nitric nitrogen to be the successive achievements of two different groups of bacteria (builders of nitrites and nitrates), it was determined by Omeliansky that the nitrogen of the organic substances must have been previously converted by other bacteria to ammonia. Disturbances can easily occur in this work, since these bacteria are most sensitive to dissolved substances. Thus, for example, the activity of the organism forming nitric acid stops absolutely if any traces of ammonia are present.

In contrast to the above, numerous other species of bacteria (more than twenty have already been identified) possess the *ability of denitrification,* i. e., the reduction of the saltpetre to free nitrogen which passes off into the air. People have wanted to trace to this process the fact that *fresh stable manure,* under certain circumstances, injures the saltpetre contained in the soil and that *straw fertilizing* acts disadvantageously. This phenomenon is now chiefly explained by the fact that protein forming organisms have laid hold of the available nitrogen in the soil. (Pfeiffer and Lemmermann as well as Gerlach and Vogel). These bacteria transform the saltpetre first into the nitrite and then into protein-like compounds. That definite secondary conditions belong here is shown by Hiltner's experiment in which straw fertilizing was proved to be very injurious for potted plants, while the same amounts on open land had a beneficial effect. This contradiction may probably be traced to the fact that the protein thus produced can be transformed more quickly in open ground to products which can be utilized again.

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[1] (Page 89 in the German edition.)

In studying the conversion of nutritive substances and their transformation by soil bacteria, the process of the *storage of nitrogen*, i. e., the assimilation of free nitrogen by bacteria, is to be considered. Besides the anaërobic *Clostridium Pastorianum* (Pasteurianum), determined some time ago by Winogradski, which with sufficient amounts of carbo-hydrates can make use of the atmospheric nitrogen for its nutrition,—aërobic species have been found by Beijerinck such as *Azotobacter chroococcum*. This species, present in every field soil, consumes extremely large amounts of carbo-hydrates by its nitrogen assimilation (according to Gerlach and Vogel 8.9 mg. nitrogen in 1 gram grape sugar).

The changes in *forest litter* should be included here. The nitrogen enrichment due to them has been caluculated by Henry[1]. He emphasizes that nitrogen is stored up with the decomposition of dead oak and beech leaves and spruce needles. This decomposition is very active on damp soil in summer, but scarcely noticeable in winter, or when mixed with soil. According to his calculations, fallen oak leaves accumulate 20 kg. of nitrogen per hectare within a year. On dry soil the dead foliage either does not become enriched at all (in the red beech), or only very insignificantly (white beech, spruce). In no case, however, was any loss of nitrogen noticed.

The active enrichment of the soil by the symbiotic tubercle-forming bacteria should also be mentioned here. Cultures of these bacteria have been introduced into commerce under the name "Nitragin"[2] and cultures of non-symbiotic nitrogen gatherers are sold under the name "Alinit." More recent investigations indicate that not only bacteria of the same species adapted to individual host plants may be assumed, but that even different species may be distinguished. Hiltner contrasts two species chiefly on account of their morphological and physiological differences; viz., *Rhizobium radicicola* and *Rh. Beijerinckii*. The activity of these tubercle bacteria in their relation to the Leguminoseae begins only when the Leguminoseae have suffered for sometime from *nitrogen hunger* and they are inactive when nitrates are present in the soil. This should be mentioned only in passing to illustrate further the dependence of bacterial life on various factors. The *root secretion* of each plant must also count as such a factor. Even the very healthy seeds which get into the soil and the green parts of healthy seedlings have a specific bacterial flora, which can increase greatly and swarm out into the soil. Other micro-organisms can be pressed back by these[3]. From such inequalities of the growth conditions in the soil must arise necessarily significant fluctuations in the individual number of each species of bacteria and thereby in the whole achievement so far as the production of nutriment favorable for culti-

[1] Henry, E., Ueber die Zersetzung der abgefallenen Blätter im Walde etc. (Annal. Sc. Agron. franc. VIII). cit. Centralbl. Agrik. Chem. 1904, p. 793.

[2] In regard to soil inoculation, it should be taken into consideration that bacteria, like all plants, will thrive only when the soil is so constituted that it favors their increase. As Remy has very characteristically expressed it, **"they must find their proper soil climate."**

[3] Düggeli, M., Die Bakterienflora gesunder Samen etc. Centralbl. f. Bakt. II. 1904, Vol. XIII, p. 198.

vated plants is concerned. If now, for various reasons, as, for example, specific root secretions, certain species of bacteria, which are attracted to any definite plant variety and incited to great increase, carry over various nutritive substances, primarily, nitrogen, in a form unfavorable for the cultivated plants, it can happen that chemically the supply of nutritive substances may be sufficient, perhaps even abundant, and yet the product may fall off. We then face the phenomena of *soil exhaustion* or "fatigue." Hiltner mentions experiments in reference to this. He perceived definite indications of soil exhaustion in the third generation of peas, which during a period of three years were grown seven times in pots in the same soil, but differently fertilized. "The plants became sick, were easily susceptible to attack, turned yellow prematurely and gave poor seeds." In the later generations, the diseased conditions were overcome in this experiment. "The roots of the pea plants were now noticeably browned, but were perfectly white and healthy inside, and it could be proved that a regular bacteriorhiza was present, which, formed by well-adjusted, beneficial bacteria, prevented the further penetration of the injurious organisms."[1]

In regard to the exhaustion of the grape, Behrens (loc. cit., p. 110) cites the observations of A. Koch, according to which it could be produced by an accumulation of injurious micro-organisms. After sterilizing the diseased soil (not the healthy soil), the growth of the vines improved.

If such a change in the composition of the bacterial flora takes place in a direction injurious to cultivation, it explains the increase of soil exhaustion due to the repeated growth of the same plant on any given piece of land, with short intermissions. And this accumulation of destructive elements is of importance not only for the bacteria, but also for other vegetable and animal enemies which can cause soil exhaustion.

Among the bacteria which accumulate in the soil with repeated cultivation of the Leguminoseae, Hiltner found that the *pectin fermenting organisms* became active. He found that in soil greatly exhausted by peas, perfectly healthy pea seed rotted especially because of these bacteria known as acid formers.

Another variation in the normal work of soil bacteria is the *turning the fertilizer to peat.* In heavy soils, often after some years, the fertilizer has been found pretty much undecomposed. In the same way *green manure* turned under too deep, turns to peat. As a result of the limited supply of air, the *formation of raw humus* is completed. The end and aim of working the soil, however, is the production of a suitable humus covering, for by the humus we obtain an equalization of the extremes of heat and cold, moisture and drought and the suitable nutritive soil which alone makes the existence of most bacteria possible. If this is present, field soil can develop its actual life, which, to a certain degree, is measurable by the production of carbon dioxid. How the bacteria co-operate in this, is shown by some statements

[1] Bodenpflege und Pflanzenbau. Arb. d. D. Landwirtsch.-Ges. Part 98, p. 74.

of Stoklasa and Ernst[1], who reckoned the respiratory intensity from 100 g. of dry substance of the *Bacterium Hartlebi,* a denitrifying bacterium, to be 2.5 g. of carbon dioxid per hour; in the same amount of dry substance of *Clostridium gelatinosum,* an ammonia former, the culture gave 2.0 g. carbon dioxid. The fact that the carbon dioxid production of a field is actually dependent primarily, on bacterial life, is demonstrated by the circumstance that no carbon dioxid was produced in observable quantities after experimental earth had been sterilized.

We find the following statements in the work of the above named authors on the influence of *aëration.* Forest soil taken from a deep position gave 59 mg. per kilo. of carbon dioxid within 24 hours in aërobiosis 0 mg. in anaërobiosis, while peat soil yielded 41 mg. in aërobiosis and 7 mg. in anaërobiosis. Naturally, heat and moisture also act determinatively. The greater the production of carbon dioxid in a field, the more completely does the chemical process of the *combination of the free ammonia take place,* as Schneidewind[2] has observed. This question comes under consideration here in as much as the losses in nitrogen with an addition of animal manure represent an impoverishment of the stores in the soil. If stable manure with ordinary treatment is left in a manure pit, it shows a nitrogen loss of 30.31 per cent. after lying three months. If it lies, however, on an underlayer of old manure, producing a great deal of carbon dioxid, the loss amounts only to 16.94 per cent. Here the abundant carbon dioxid must have combined the free ammonia or have prevented the disassociation of the ammonium carbonate already formed.

Among the most serious injuries, because the most frequent, belongs the so-called "unripe soil." This is distinguished by its lack of elasticity from the ripe soil which, under the influence of the soluble salts in the soil and the micro-organisms, takes on the friable structure already described. In consideration of the great work which the bacteria perform in soil decomposition, we can assert that the ripeness of the soil is due to their work. If we do not know by far all the processes taking place in ripening soil, we do know that we may consider the ripening up to a certain stage as actual fermentation. Attention need be called here only to the special pectin fermenting organisms (Plectridia) which seem of importance in germinating seeds of the Leguminoseae and further to the cellulose fermenting organisms with the great formation of hydrogen and methane (marsh gas CH_4). Further, the Streptothrix species come under consideration as humus fermenting organisms, but especially the granulose organisms forming acids[3], which produce chiefly butyric acid and carbon dioxid. In this, the Plectridia take over the chief share in the mineralization of the organic substances.

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[1] Stoklasa, J., and Ernst, A., Ueber den Ursprung, die Menge und die Bedeutung des Kohlendioxyds im Boden. Centralbl., für Bakteriologie etc. Section II, 1905, Vol. XIV, Nos. 22 and 23, p. 725.

[2] Schneidewind, Zur Frage der Stalldüngerkonservierung. Deutsche landw. Presse 1904, No. 73.

[3] Löhnis, F., Ueber die Zersetzung des Kalkstickstoffs. Centralbl. f. Bakt. II, 1905, No. 3-4, p. 87.

The nitrogen collectors (*Bacillus radicicola* and *B. megaterium, Clostridium Pasteurianum,* Azotobacter) as also the ones forming ammonia (*Bacillus ureae, B. albuminis, B. proteus vulgaris*[1], *B. butyricus, B. mycoides, B. subtilis, B. mesentericus vulgatus, B. foetidus, Bacterium coprophilum, etc.*) the nitrifying *Bacterium nitrobacter,* etc., and the denitrifying genera (*Bacillus mycoides, B. substilis, B. liquidus, B. nubilus, B. vulgaris, B. coli, B. prodigiosus, B. liquefaciens, Bacterium fuscum, Closteridium gelatinosa,* etc.), have been considered and attention should now be called to the specific organisms of decomposition. All these biological processes are enacted in ripe soils, supplementing or combatting one another, according to the climatic conditions of the soil at the time.

Besides bacteria, *green algae,* the appearance of which counts as a sign of good ripening, have been considered to be nitrogen collectors. According to Koch[2], however, this is not the case, but their value lies in the fact that by their chlorophyll activity they furnish carbon for the soil bacteria, which combine nitrogen. Beijerinck, Schlösing and Laurent insist that the blue-green algae can assimilate free nitrogen and, according to Saida[3], a number of mold fungi should also have this ability.

As Treboux[4] has recently emphasized, the activity of the nitrite and nitrate bacteria may frequently be lost, but the ammonia retained in the soil is always at the disposal of the plants and used up by them; this may still be taken for granted for many cases. Other investigators have also proved the usefulness of ammonia. Ultimately, however, the formation of the ammonia in the soil is based on the decomposition in which bacteria participate.

The growth of the majority of micro-organisms affecting the fertility of the soil is connected with an abundant *fluctuation in moisture,* and the passage of heated air over the soil with its drying effect. These conditions are lacking in heavy soils in wet periods,—i. e., the soil remains unripe. Here the cultivation of useful soil bacteria succeeds only with a constant working of the soil. Acknowledged practical workers recommend the quickest possible turning over of the grain stubble on loamy soils in order to obtain a greater nitrogen gain by an earlier soil ripening. In the Lauchstadt experiment station about the same results were obtained by *early ploughing* as by a green manuring. In spring planting on all heavy soils, a fall ploughing is the best precaution against unripe soils.

Recently, *letting the ground lie fallow*[5] has again come into use for heavy soils. In light soils it should be considered a wasteful process. The benefit of letting ground lie fallow is its disintegrating action; no final de-

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[1] Stoklasa, J., Ueber die Schicksale des Chilisalpeters im Boden etc. Blätter f. Zuckerrübenbau 1904, No. 21.

[2] Koch, A., Bodenbakterien- und Stickstofffrage. Verh. d. Gesellsch. deutcher Natur. zu Kerlsbad. 1903. Part I, p. 182.

[3] Vogel, J., Die Assimilation des freien elementaren Stickstoffs durch Mikroorganismen. Centralbl. f. Bakteriol. II, 1905. Vol. XV, p. 174.

[4] Treboux, O., Zur Stickstoffernährung der grünen Pflanzen. Ber. d. botan. Gesellsch. 1905. p. 570.

[5] Hillmann, Bedeutung der Agrikulturphysik etc. Nachrichten aus dem Klub der Landwirte, 1902, No. 453 and Mitteil d. D. Landw.-Ges.

cision has been reached as yet as to how this effect is produced. It is thought that in this, physical, chemical and soil bacteriological processes interact supplementarily. The frequent thawing and freezing in the winter serves to break and loosen the soil. Thus the action of the atmospheric processes is favored and the soil opened for the beneficial species of bacteria. It has not been determined with certainty to which genera these belong. Hiltner has proved first of all, that they are not the Alinit bacteria. In the end the usefulness will be decided by the greatest accomplishment of the nitrifying bacteria; for, according to Reitmair[1], the nitrification in good mild soils with sufficient heat begins immediately after the fall harvest in such a way that the nitrate requirement of the subsequently planted grain will be met until the next spring. In this, however, a suitable friability and a definite calcium content is taken for granted[2]. (See also the statements under Drain Water.)

Naturally it must be emphasized with Stutzer[3] that the land may be allowed to *lie* fallow only under certain fixed circumstances. It is thought that this may be done if it seems financially most advantageous for the agriculturalist to do without the field for the long time while it is lying fallow, rather than to use the more quickly acting green manure and stable manure. When working with soils tending to unripeness, emphasis should be laid on this lying fallow only because it loosens the soil mechanically and does not affect the fertilizing salts. The nitrogen of the organic fertilizing masses seems, as Pfeiffer[4] especially emphasizes, to be held fast in the soil, capitalized as it were, and then shows a long subsequent action. This author is, however, an opponent of the theory of letting ground lie fallow, which he characterizes as a robber cultivation, so far as the stock of nitrogen is concerned. He sees in this an incomplete restitution of the amounts of nutriment removed from the soil by the crops. In Pfeiffer's opinion, the soluble nitrogen compounds obtained by letting the land lie fallow are lost again in great part from uncultivated soils by the water which soaks through. Such considerations, in my opinion, are entirely justifiable for light soils, but do not hold good for heavy soils provided with an abundant absorptive power by the clay and weakened by the harvests.

2. Relation of the Nutritive Substances to the Plants.

The phenomena treated in this and the following division, are rarely the result of only a lack or an excess of the nutriment in the soil. They are usually the result of the co-operation of numerous factors, among which atmospheric humidity plays an especially decisive *rôle*. We will not forget that almost all diseases are produced by an *unsuitable combination* of the

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[1] Reitmar, O., Die Stellung der Brache und der Gründüngung in unsern modernen Fruchtfolgen. D. Landw. Presse. Sond. 1903.

[2] Wohltmann, F., Fischer, H., and Schneider, Ph., Bodenbakteriologische and bodenchemische Studien aus dem Poppelsdorfer Versuchsfelde. Journ. f. Landwirtschaft 1904, p. 97.

[3] Stutzer, A., Die Nutzbarmachung des Stickstoffs der Luft für die Pflanzen. D. Landw. Presse 1904, Nos. 10-19.

[4] Pfeiffer-Breslau Stickstoffsammelnde Bakterien. Brache und Raubbau. Berlin, P. Parey, 1904. cit. Centralbl. f. Agrik. Chem. 1905, p. 599.

normal vegetative factors and are disturbances in the equilibrium of the interacting nutritive processes whereby certain ones are repressed while others predominate.

If we now speak of diseases due to a lack, or an excess of moisture and nutritive substances we also involve in this the phenomena in which atrophies and hypertrophies occur in various parts of the plant body. These need not arise from an actual lack or excess of moisture and nutritive substances, but are simply produced by the unfitness of the plant, from the combination of the factors of growth, to nourish all its organs advantageously for the development of the whole. The absolute phenomena due to lack and excess are approximated on this account by the relative ones in the form of disturbances of the local equilibrium.

A. Lack of Moisture and Nutritive Substances.

a. Lack of Moisture.

Influence of the Various Plant Coverings.

After having considered the physical processes leading to a lack of moisture in the soil, and after having discussed a number of phenomena of diseases arising therefrom, we must consider supplementarily the influence which the covering of vegetation itself exercises on the water content of the soil. On the same soil, with the same atmospheric conditions, a cultivated plant will find a supply of moisture sufficient for its development on one part of a field, and not on another part, if on the former some species has been grown which makes a small demand on the water content. Therefore the *preceding crop* is of significance for each planting.

As Wollny[1] has determined, the water content is less in the root region of a planted field than in the corresponding layers of the naked soil. The more luxuriant the plant growth and the thicker and longer lived, the more water is lost from the soil. Experiments have not determined any fixed scale for the use of water, yet they indicate that, on an average, the evergreen conifers require the greatest quantities while deciduous trees and perennial fodder plants follow in a descending scale and the superficially rooting field plants make less demand on the whole supply of the water in the field. Of the latter group, the large, richly leaved, erect Papilionaceae, such as the field and bush beans, seem to require the most water at the time of their chief development, while the roots and tuberous plants cultivated in wide rows should be named last. In summer the perennial fodder plants use somewhat greater quantities than field plants and conifers. This is reversed in the spring and fall. In winter the requirements of the different plants equalize, except the conifers, which in mild winter weather constantly withdraw definite amounts of water from the soil.

[1] Wollny, E., Ueber den Einfluss der Pflanzendecken auf die Wasserführung der Flüsse. Vierteljahrsschr. d. Bayer, Landwirtschaftsrates 1900, p. 389.

v. Seelhorst[1] treats the same subject and comes to the conclusion that so far as moisture is concerned, rye exhausts the field much less than wheat. This circumstance is very important when planting possible subsequent crops for green manuring, for, after wheat, which is cleared later from the field, this crop not only reaches the soil later, but also finds the soil much drier. Clover exhausts the water in the soil very greatly so that, aside from the fact that the soil easily becomes loosened by the clover stubble, in dry years, the winter crops following the clover can only develop slowly and unevenly because of the lack of moisture.

On the other hand, the potato, at least the variety ripening moderately early, seems to form a very good early crop, since it leaves the soil fairly moist. Peas also form a good early crop for winter grain. Oats are considered by v. Seelhorst to be especially unfavorable, not so much because they exhaust the nutritive substances as because they remove water to so marked an extent.

In connection with field plants, we should consider also the *injurious influence of grass*. It is easy to understand that a close turf keeps water from the roots of plants, especially fruit trees and impoverishes the friable soil, but recently a direct poisonous effect of grass[2] has been mentioned which may possibly be due to the fact that beneficial bacteria species are suppressed by it and injurious ones favored. In the case given, the roots of the apple trees were long, abnormally thin and browned, the leaves were very light in color and dropped 4 days earlier. The foliage was sparse, the wood growth scanty. As soon as the roots or even only a greater part of them reached soil not covered by grass the phenomena of disease disappeared. These phenomena agree essentially with those produced on heavy, impervious soils, with a scarcity of oxygen, so that it seems in no way necessary to assume any poisonous action. We find, in many cases, especially on light soils, that the turf does no injury, if care is taken to have nutritive substances within reach of the roots. On close clay soils, the grass is kept green for a long time by the water rising by capillary action from the subsoil, thereby removing a great deal of moisture from the subsoil without returning it in quantities worth mentioning during the period of vegetation, since the grass uses the atmospheric precipitation itself.

Wilting.

In discussing "physiological wilting," mention was made of the fact that the phenomena of wilting can appear even with an abundance of moisture in the soil, since the roots function incompletely. In soils with a high content of soluble salts, the water, under certain circumstances, can be held so fast that the roots meet their need only with great difficulty. Phenomena

[1] v. Seelhorst, Untersuchungen über die Feuchtelgkeitsverhältnisse eines Lehmbodens unter verschiedenen Früchten. Journ. f. Landwirtsch. 1902. Vol. 50. cit. Centralbl. f. Agr. Chemie 1903. Part 6.

[2] Bedford, Duke of, and Pickering, Spencer U., The effect of grass on trees. Third report of the Woburn exper. fruit farm. London, 1903.

then become evident, which can also be produced experimentally by the use of highly concentrated nutrient solutions:—short internodes, smaller leaves, short roots having a great tendency to decay, reduced production and transpiration. A further cause of wilting is a lowered soil temperature. If a degree of heat is not reached which is required by a certain plant so that the roots can begin absorbing the water, while the temperature of the air permits evaporation by the leaf apparatus, this disturbed equilibrium between water demand and supply makes itself felt by wilting.

A special, not rare case, is the *wilting of hot bed plants* when the pots are cooled during the re-working of the hot beds or during transplanting. Inexperienced gardeners then water the plants abundantly and the turgidity is restored if the water, previously warmed, awakens root activity. By a repetition of the cooling, the same experiment can be carried out until finally the pot is overloaded with water and the roots break down from a lack of oxygen.

Another case of the wilting of potted plants was observed by Hellriegel. He found that plants wilted in *large pots,* which held three or four times as much water as small pots of plants of the same species, which did not wilt. This circumstance is explained by the relative water content of the soil, which in the small pots amounted to 14 to 20 per cent., while the absolute larger quantities of water in the larger amount of soil in the large pots was so disturbed that it represented only 11 to 15 per cent. of soil moisture. In this case, absorption was made more difficult for the roots in the larger pots, by the less easily transported water held more firmly in the capillaries of the soil, so that evaporation was in excess.

In contrast to this physiological wilting we might term mechanical wilting those phenomena due to an actual lack of soil moisture because the mechanical transportation of water slackens in the ducts. Naturally with the great demand for moisture in the leaves and the scanty reinforcement in the ducts, the air content increases and in this *increase of the air content* above a certain degree may be seen the arrest of the water current in the axial organs, as Strasburger[1] emphasizes. In this, the air in the tracheal elements will be more dilute, as the transpiration and assimilation on warm days[2] are stronger, and the result is that a moistening of the soil becomes so much the more quickly effective. In general, watering exerts a lesser influence, the greater the turgidity of the plant[3]. The great tracheal air dilution shows itself also in the well-known fact, that field plants, wilting rapidly in hot weather, will stiffen from the dew on the soil at night,—especially since leaf evaporation is repressed at this time.

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1 Strasburger, Ed., Ueber den Bau und die Verrichtungen der Leitungsbahnen in den Pflanzen. Jena 1891. cit. Bot. Zeit. 1892, p. 261.

2 Noll, Ueber die Luftverdünnung in den Wasserleitungsbahnen der höheren Pflanzen. Sitzungsber. d. Niederrheinischen Ges. f. Natur- und Heilkunde. Bonn 1897, II. p. 148.

3 Chamberlain, Houston Stewart, Recherches sur la sève ascendante. cit. Bot. Jahresb. 1897, p. 78.

Change in Production Due to Lack of Moisture.

The difference in the harvest yield, resulting from a lack of moisture, has also been considered in previous divisions, so that here we need cite supplementarily only a few other cases. Hellriegel's[1] experiments are most decisive. Two tests of clover were taken from a field, in which, in places, the plants had begun to wilt. There was found:—

In wilted plants........	Leaves 71.0 per cent. water,	petioles 78.4 per cent.
	Leaves 71.1 " " water,	petioles 80.8 " "
In turgid leaves among the wilted ones........	Leaves 82.5 " " water,	petioles 90.0 " "

The wilted leaves contained in the leaf-blades ca. 29 per cent. of dry substances; in the petioles, 19 to 21 per cent.; while the turgid leaves contained in their leaf-blades 17.5 per cent. and in the petioles 10 per cent.,—i. e., only about half that of the wilted plants.

An example of the influence of drought on grain is given by Prianischnikow's[2] investigations, according to which the nitrogen content increases in corn, if the moisture decreases. Stahl-Schroeder's[3] studies give a more detailed representation of the influence exerted by the taking up of nutritive substances and their assimilation in dry years. After mentioning the well known fact, that phosphoric acid hastens ripening, while nitrogen and potassium delay it, he notes the importance of the months before blossoming for the taking up of the nutritive substances. If the soil moisture is deficient at this time, the organic substances will be in smaller quantity. But the nitric acid, which penetrates easily through the cell walls, will find its way into the plants and in its turn again incite the taking up of phosphoric acid, in order to effect the formation of the proteins. In this way, in dry years, scanty harvests are produced with a high nitrogen and phosphoric content. The nitrogen increase becomes the more evident, since, with drought, the grain stores up the starch with much greater difficulty. The reverse may be determined in the Norwegian corn tests, the high absolute weight of which is caused by an abundant starch deposit. This is explained by the growth of the grain with abundant moisture under the influence of the long days.

In Hellriegel's experiments with barley, in pots filled with sand, we find, expressed in exact figures, the lowering of production, as the amount of moisture at the disposal of the plant is reduced.

Soil moisture in percentages of saturation capacity.	Dry Substance in Straw and Chaff	Dry Substance in Grain	
80—60	7394 mg.	4896 mg.	averages for 3 Plants
60—40	5988 "	4133 "	
40—20	4842 "	1942 "	

[1] Loc. cit. p. 544.

[2] Prienischnikow, Ueber den Einfluss der Bodenfeuchtigkeit auf die Entwicklung der Pflanzen. Journ. f. experim. Landw. 1900. Vol. I, p. 19.

[3] Stahl-Schroeder, Kann die Pflanzenanalyse uns Aufschlufs über den Gehalt an assimilierenden Nährstoffen geben? Journ. f. Landw. 1904. cit. Biedermann's Centralbl. f. Agr. Chem. 1905. Part 2.

The pots with a soil moisture under 20 per cent. of the saturation capacity of the sand suffered so much from the summer heat, that the heads in the upper leaf sheaths stood still, without advancing to the formation of kernels.

In apparent contradiction to such results stand the observations of practical agriculturalists that in perfectly dry, so-called dust-dry soils, the plants can keep on growing, although nutritive substances are entirely lacking in the subsoil (it is sterile). Such cases are explicable as soon as the sterile subsoil contains water and the roots remain in the moisture. Haberlandt[1] studied this case experimentally. He let the lower part of the roots of his experimental plants dip into distilled water, while the upper roots remained in soil layers, which, as shown by control experiments, were so dry that plants wilted in them. The plants of which the outermost roots dipped into distilled water showed a marked increase in dry substances; from this it is evident that the roots found in the dry soil must have taken up the mineral substances. This division of labor by the roots explains the growth of our cultivated plants in spite of dry surface soil when their roots reach deep into a sterile, but moist, subsoil.

According to Hellriegel, these changes in production, so well shown in grain, take place in the same sense in other cultivated plants.

Discoloration of Woody Plants.

The typical result of a lack of moisture and abundant illumination is the vigorous development of the mechanical tissues. We need refer only to the conditions found in dry climates. For example, Jönsson[2] reports that, among other characteristics of arid plants, the walls of the epidermal cells often become slimy. In Haloxylon, Eurotia, Calligonum, Halimodendron, layers of slime cork alternate with those of common cork. The *slime cork* is very capable of swelling and is laid bare after the protective cork splits, so that it can take up water and hold it. Cells containing slime are found also in the assimilatory tissues. In Halimodendron, the secondary bark often becomes thick and spongy, thereby modifying the temperature extremes and easily storing up water. In the peripheral parts, abundant secretions of salts form a protection. These characteristics vary in regions where the water supply is abundant in the soil and in the air. Thus, for example, no slime cork is found in Halimodendron when grown in Copenhagen.

Swanlund[3] reports from new Amsterdam on the extremely thick outer walls of the epidermis, the frequent depression of the stomata, the rolling in of the leaves with the resulting restricted transpiration. We have touched upon this subject earlier in the divisions on differences in latitude and on the defects of sandy soils and at the same time have considered the nature of

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[1] Cit. Biedermann's Centralbl. f. Agr. Chem. 1878, p. 314.

[2] Jönsson, B., Zur Kenntnis des anatomischen Baues der Wüstenpflanzen. Lunds Univ.-Arsskrift XXXVIII. Bot. Jahresb. 1902, II, p. 292.

[3] Swanlund, J., Die Vegetation Neu-Amsterdam's und St. Pauli's in ihren Beziehungen zum Klima. Dissert. Basel 1901.

the *red coloration*. By artificial interference, a localized lack of moisture and thereby a formation of anthocyanin is stimulated if the leaves of plants, of which a red autumnal coloration is characteristic, be nicked or the branches girdled. Then in the middle of summer a red color appears on the upper parts above the injury.

In regard to the phenomena of discoloration produced by heat and drought, I will give some observations from 1892, in which year, in August, unusually high temperatures occurred together with hot winds. I found on the 19th of August a temperature of 52.7°C. on especially heavy loam soil. All the plants wilted and the majority gradually lost their foliage. Naturally great individual differences were also noticeable.

The leaves became discolored and fell, the lowest leaves of the branches being the first affected.

In the Alder, the leaves fell without losing their green color.

Acer Pseudoplatanus var. *Schwedleri*, the under side of the leaf is red. From the tips backward the intercostal fields of the leaves turned a reddish brown to leather color. Besides this, deep brown, perfectly dry rust spots were scattered irregularly over the surface of the leaf. The injured leaves remained in place.

Acer Negundo. The upper leaves were somewhat flabby. The edges of the leaflets were *curled upward*. The leaves next below were a pale yellowish green, the lowest light yellow, uniformly rolled up on the dry edges.

Acer plantanoides. The leaves show on their under side pale yellow, irregular, small *rust spots* running into one another and extending between the ribs. The dried tips bend upward like hooks.

Fagus silvatica. On the various leaves, not always the lowest, but the most exposed, were irregular, dry places with yellow, faded edges in the intercostal fields. At times, the whole upper surface is equally lightly browned. There is never any outlining of the edges.

Vitis vinifera. At the beginning of the drought, among the normal green leaves are found yellowish ones. The lemon yellow discoloration, red in other varieties, begins at one place on the edge and advances into the intercostal fields until only the veins seem green. In spite of the drought, I found on various lower leaves the dry, angular spots of *Plasmopara viticola*.

Prunus Persica. All the leaves are somewhat languishing, some (but not always the lowest) turning yellow from the tips backward. On some trees, the discoloration advances more quickly along the veins so that at first the veining and then the rest of the surface of the leaf colors yellow-red to wine-red. Then the leaves drop. (Peculiarity of the variety).

Prunus domestica. All the leaves are flabby. The majority, however, are still uniformly green with the exception of the lowest, which on many branches have become a whitish yellow and have slender, brown, reflexed, dry peripheral spots. Easily shaken off by the wind.

Prunus avium. The lower leaves, especially on the short shoots (brachyblasts), turn a uniform lemon yellow and fall.

Prunus Cerasus. Only a few leaves turn yellow, otherwise the entire foliage is still fresh. *A proof that the cherry loves drought.*

Pirus communis. According to the exposure rust spots are found in greater or less numbers showing, however, no yellowing. At times dry areas appear on the edges of the leaves, but more frequently the whole surface is a dark umber brown (the under side lighter in color with a still fresh green or lightly brownish mid-rib). The edges strongly rolled upward. Because the petioles remain green, the injured leaves do not fall at all or only much later.

From these and numerous other observations it is evident that, on an average, the parts of the leaves furthest from the veins discolor and dry first and most. When periods of heat follow one another rapidly with a strong sun action, the rust spots become very conspicuous; with a lesser intensity of the sunshine, a general discoloration in the form of spots prevails.

Here belongs also the especially strong development of anthocyanin in dry, poor localities, which becomes noticeable even in the arctic regions, where the red coloration with the strong illumination is a prevailing phenomenon. Wulff[1] cites a very characteristic example. He found in places, fertilized by the excreta of birds, that the formation of anthocyanin disappeared in plants of which the vegetative organs seemed strongly reddened in arid regions.

Finally, there must be considered the decrease in the power of movement of clover leaflets and related organs, with a continued lack of moisture. In *Mimosa pudica* the periodic irritability is lost and the leaflets remain open,—"drought cramp."

The Red Coloration in Grain.

The red coloration in grain in continued dry, hot summers has often called forth the theory that parasitic influences participated in it. Klebahn[2] tested more closely a special case, which was universally striking because of its wide distribution and intensity. He found that the red coloring matter appeared gradually in place of the cholorophyll. While the alcoholic extract of normal leaves appears green, it is colored only slightly yellow in red

[1] Wulff, Thorild, Botanische Beobachtungen aus Spitzbergen, Lund. 1902. In regard to the theory at present generally held that anthocyanin is said to form a protection for the chlorophyll against an excess of light, Wulff (p. 67) calls attention to Engelmann's investigations from which it is evident that the light absorption of the red anthocyanin is complementary to that of the chlorophyll and accordingly does not retard the decomposition of the carbon dioxid. "This fact has moreover proved most fully the untenability of the Pringsheim-Kny-Kerner theory of protection from light." Wulff sees the advantage of the anthocyanin in its greater storage of heat. As I have mentioned already, I am unable to accept the above utility arrangements or the expressions of a "finality" in the organism and I perceive everywhere the necessary phenomena resulting from definite combinations of the factors of growth. The formation of anthocyanin seems to me to be the result of an excess of light on the cell content, rich in free acids, at the disposal of which there is no assimilate containing sufficient nitrogen. This condition can be produced, as in plants of cold regions, by a lack of heat; in other cases by a scarcity of water, a decreased supply of nutriment, etc.

[2] Klebahn, H., Einige Wirkungen der Dürre des Frühjahrs 1893. Zeitschr. f. Pflanzenkrankh. 1894, p. 262.

leaves in which the cholorophyll has been destroyed. The red coloring matter is soluble in water and glycerin, insoluble in alcohol and turpentine, turning blue with potassium and ammonia and again red with acids. It is in combination with the cell sap, partly in the epidermis, partly in the assimilatary tissue. In oats, the development of the reddened plants and their grain production was proved to be less than that of green ones. We have just made a study of the reddening of grains[1] and, in agreement with Klebahn, have come to the conclusion that in this redness only phenomena of a premature ripening are to be seen, together with a lack of moisture and great intensity of light. In our treatise will be found also anatomical details as to the *blasting* and the appearance of the so-called *"drought spots."* A yellow coloration of the walls of the bast fibres is worth noticing, which increases to a yellow brown, as is also the hardening of the cell contents in various groups of the assimilatory tissues.

The death of leaves, due to sudden heat periods, should be distinguished from a normal death. The leaf does not shrivel up as completely as the normally ripened one,—i. e., a leaf, the contents of which are nearly exhausted—or it can do so only in places. In the normally ripened leaf, only the entirely impoverished cells of the leaf tissue, which therefore collapse to a waved folded layer, are found between the epidermis of the upper and of the lower sides, while in the former leaf just the remaining, more abundant contents stiffen the walls by drying, thereby more or less preventing the collapse.

I also found the same discoloration phenomena in wild grasses (Arrhenatherum) and expressed a warning against deceptions from anatomical investigation. Especially angular or spherical masses appeared in the contents which reacted with iodine like starch and thereby could give the appearance of a still existing, greater assimilatory activity. The other reactions prove, however, that "residue bodies" of the chlorophyll decomposition are here involved which belong to the *carotin group*. They could be compared with adipocere.

"Reds" of Hops.

The disease, called by practical growers *"summer rust," "Fox" or "red tan,"* consists in a spotting of the leaves, which advances from their bases. The spots attack the peripheral parts as well as the tissue groups lying between the different veins. By a partial destruction of the chlorophyll, the diseased places at first appear yellowish, then reddish and finally dry and browned. In the meantime the leaf continues longer in a wilted condition, finally, it shrivels and drops off, while the upper, younger parts of the vine are still fresh, green and developing. The new structures produced during this time are smaller in comparison with those of other plants which are unaffected and have not lost the lower leaves. If the disease remains restricted to the lower parts of the vine, the injury is not important; but, if it attacks

[1] Sorauer, P., Beitrag zur anatomischen Analyse rauchbeschädigter Pflanzen. Landw. Jahrb. 1904, p. 596, Plates XV to XVIII.

the upper portions with the blossoming catkins, the harvest will be very light and an immediate gathering is advisable.

The disease may be confounded easily with the *"copper rust,"* caused by the weaver moth, but is distinguished by its location since the copper rust colors the leaves on the upper part of the vines a reddish yellow and is recognizable from its finely spun threads on the underside of the leaf, while the summer rust causes a yellowing and drying of the leaves, beginning at the base of the vine. It is a sapping of the older organs by the younger ones, which require the organic material there present for their further development.

The so-called *"Pole Red"* seems to correspond to the "blast" of grain and to be the result of a sudden dry period when the catkins mature.

In this and the related diseases of reddening the lack of atmospheric moisture plays an especially decisive *rôle,* because watering only the soil rarely proves a remedy. It is better, if possible, to water regularly in the evening. But for larger areas in practical cultivation the necessary number of laborers and the great quantities of water may rarely be had. Hence resort must be had to preventative measures, in which either the excessive evaporation is reduced by extensive *shading,* or the saturation capacity of the soil is increased by the supply of fertilizing salts (not animal manure). Fr. Wagner[1] cites an example for the later case. He found in his cultivation that hop vines, without having been given nitrates, did not resist drought and vegetable or animal parasites so well as those fertilized with chili saltpetre and also their lower leaves turned yellow earlier. In the same way it has often been observed in practical agriculture that fodder and sugar beets withstand drought better when the soil has been fertilized with potassium salts or nitrates, or even with abundant stable manure[2].

Similar discoloration resulting from a lack of moisture has been observed in *flax.* This is described partly as the "Reds" (*le rouge*) and partly,—when the points of the stems turn yellow prematurely,—as the *"yellows"* (*le jaune*).

"Leaf Scorch"—"Parching of Vines"—"Red Scorch."

The above are collective names for a group of phenomena distinguished with difficulty from one another, in which the leaves are colored red. As a rule, the discoloration is followed by a partial or complete drying up of the foliage, which begins to fall prematurely. Recently Müller-Thurgau[3] has determined a parasitic cause for a definite form of reddening[4] and takes pains to emphasize the characteristics, apparent to the naked eye, distinguish

[1] Wagner, Fr., Salpeterdüngungsversuche des Deutschen Hopfenbau- Vereins Wochenbl. d. Landw. Ver. in Bayern 1904, p. 182.

[2] See, for example, Jahresb. d. Sonderausschusses f. Pflanzenschutz für das Jahr. 1904. Arb. d. Deutsch. Landw.-Ges. 1905, p. 91.

[3] Müller-Thurgau, H., Der rote Brenner des Weinstocks. Centralbl. f. Bakt. II, 1903. Parts 1-4.

[4] Another form of Red Scorch connected with Botrytis vegetation is described by Behrens (Untersuchungen über den Rotbrenner der Reben) in Ber. d. Grofsh. Bad. Versuchsanstalt zu Augustenborg 1902, p. 43.

ing this disease from others. With reference to the form of "Red Scorch," described in the second volume of this manual and caused by *Pseudopeziza tracheiphila* (see Vol. II., p. 278*) in which the discoloration often begins in the form of spots in the angles of the veins, it should be emphasized here that the leaf scorch, which is due to a lack of moisture together with strong sunshine, begins as a rule with a discoloration of the intercostal fields starting from the edge. The phenomena vary greatly, according to the variety and habitat, and at times only a shining yellow color is found instead of the reddening. The edges of the leaves often dry up. The kind of discoloration runs parallel with the progress of the summer blight in other woody plants, whereby it may usually be observed how the deficient moisture supply becomes evident at first on the parts lying furthest away from the petioles and the mid-rib and then advances until finally only the immediate surroundings of the veins remain green. (See Changes due to place of growth.)

In regard to the physiological activity, Müller-Thurgau had proved earlier that the formation of starch and its solution took place the more slowly, the less the water content of the leaves[1]; irrigated vines formed more sugar.

A phenomenon manifesting itself like the parasitic scorch has been described by Sauvageau and Perraud[2] as the *pectin disease* (*maladie pectique*), the result of continued drought. In this, the leaf blades are loosened from the petiole.

Yellowing Due to the Grafting Stock.

In our species of fruit there is often a lack of water, because a rapidly growing variety grafted on a dwarf stock, in times of great evaporation, is not able to convey the necessary water to the graft.

On good soils pears, grafted on quince stock, often turn yellow, while trees on wild stock thrive well. In dry summers I found with such dwarf trunks that well grown scions, inserted later in the bark, formed strong but yellowish shoots, while the older top was green. In this too I see phenomena of the lack of moisture due to the quince stock which (especially if planted shallow) cannot obtain the necessary water. Pears on shallow planted quinces ripen their *foliage more quickly and lose it earlier.*

Premature Drying of the Foliage.

When the foliage dies as a result of the summer drought, in which it usually hangs on the branch, because the petiole has remained fresh, the injury suffered by the tree is far greater than is generally understood.

It is thought that the injury consists primarily in the premature stopping of leaf activity and the lessened formation of wood. Kraus'[3] investigations

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* Paging in the German original.

[1] III. Jahresber. d. Versuchsstat. Wädensweil. Zürich 1894. p. 56.

[2] Sauvageau, C. et Perraud, J., La maladie pectique de la vigne. Revue de viticulture 1894, p. 9.

[3] Bot. Zeit. 1873, Nos. 26 and 27.

have proved, however, that, besides this lack of additional growth, a positive loss in substance takes place, which is much greater than in normal fall defoliation. The leaves killed by blight do not behave as do those which drop off in the fall. These have gradually given up to the trunk most of the substances still utilizable for the plant body and in the end have been loosened by a round-celled layer of separation. The dried leaves, in which no such layer has been formed, retain the elements which contain nitrogen together with phosphoric acid and only the starch with the potassium reaches the trunk before the death of the leaf. By the premature drying of the foliage approximately twice as much nitrogen and phosphoric acid are lost to the plant as by the autumn leaf-fall. This is proved by analysis of the leaves of a syringa carried through by Maerker.

In percentages of dry substances, there was contained in

	Summer blighted leaves	Autumn fallen leaves
Nitrogen	1.947	1.370
Phosphoric acid	0.522	0.373
Potassium	2.998	3.831
Calcium	1.878	2.416
All mineral substances (free from carbon dioxid)	8.028	9.636

The above amounts, if expressed in percentages of the whole ash, would be as follows:—

	Summer blighted leaves	Autumn fallen leaves
Nitrogen	24.0	14.0
Phosphoric acid	6.5	3.8
Potassium	37.3	39.7

The Burning Out of Grass.

With the drying of the turf, as the result of hot periods in summer, the loss of nutritive substances must be considered especially in meadows. Where there are no irrigating arrangements, there is no possibility of avoiding the injury. In ornamental planting, however, it may be avoided if the action of the light and thereby evaporation is repressed at the right time by mulching with hay or other light shading material. Sprinkling the grass surfaces is effective only when it can be carried out repeatedly during the day. In other cases, shading must be resorted to.

Silver Leaf.

The "Silver Leaf" belongs among the phenomena which have not yet been tested experimentally in regard to their causes and therefore can be classified only provisionally.

The disease so manifests itself in fruit trees that the leaves, otherwise normally developed, lose their dark green appearance and give a silvery, whitish reflection. As a rule only individual branches suffer and possibly

after June or July. In the following year, or in the second, at the latest in the third year, after the appearance of the silver leaf, the branch dies. In the specimens which I could examine after the lapse of a year, the phenomenon appeared often on the other branches after the dead branch had been removed, so that, for the present, I have formed the hypothesis that the silver leaf is an absolutely certain precursor of the death of a branch. It is found most wide-spread among apricots. I found the phenomenon also in plums and apples.

The change begins in the older leaves of the spring growth, the youngest more often escape; likewise the late shoots developing suddenly in old wood from preventative eyes. First of all only a certain dullness of color is found, a loss of the gloss in places and, as it seems to me, an increased amount of air in the intercellular spaces between the various palisade cells or between them and the epidermal cells. Gradually the dull places become whitish, in fact because of a glandular breaking up of the epidermal cells between the finest ramifications of the veins which remain green. This loosening up consists of a dissolving, in places, of the connection between epidermis and palisade parenchyma.

Aderhold[1], who also observed the disease in cherries and found that the cells of the epidermis mutually separate from one another, could prove that the variations from the healthy leaf, in places displaying the silver leaf, were found in the solvability of the intercellular substances (middle lamellae). He surmised that the intercellular substance in the diseased organs consisted of more soluble pectin compounds than in the the healthy leaf and, since the calcium compounds of pectic acid represent insoluble conditions, the theory is pertinent, that the disease may be due to a *lack of calcium*.

According to this theory, the disease would also belong in the group of phenomena, due to deficient moisture and nutritive substances; only it must be emphasized in this, that the content of moisture and nutritive substances in the soil cannot come under consideration here, but that only in the plant itself can it be manifested locally. And this circumstance points to disturbances in the vascular system. This is favored also by the fact that the branches with silver leaf die prematurely.

The apricots and plums which I observed showed gummosis and the apple trees suffered from the gnawing of bark beetles. It might be possible to strengthen the whole organism by rejuvenescence of the diseased trees and by supplying calcium.

The Water Core of Apples.

In the same way the phenomenon may be traced to the local vascular disturbances in which individual fruits of a tree in part, or as a whole, remain hard and become glassy and transparent,—develop less color and are tasteless.

[1] Aderhold, R. Notizen über einige im vorigen Sommer beobachtete Pflanzenkrankheiten. Zeitschr. f. Pflanzenkrankh. 1895, p. 86.

In investigating an apple, which was only partially glassy, I found in longitudinal section, that the particles of the skin were most intensively glassy and that, inside the fruit, the white, normal flesh extended from the base pretty nearly to the bud end. The glassy zone had a whitish marbling due to wedged-in groups of normal flesh. The seeds were mostly deformed, not ripe and still white. The healthy part contained abundant starch and intercellular spaces strongly filled with air. These spaces were poorer in air in the glassy part and there was no starch except in isolated, wedged-in cell groups. The glassy part turned brown more quickly in the air; some dextrin could be found together with abundant grape sugar. In dry substances there was found in

	The healthy half	The glassy half
With the skin	21.48 per cent.	19.43 per cent.
Without the skin	20.24 " "	17.97 " "

Aderhold[1] found in

	Healthy fruit flesh	Glassy fruit flesh
Specific gravity	0.718	0.925
Dry substances in percentages of the fresh weight	14.44 per cent.	12.60 per cent.
Ash in percentages of the dry weight	2.093 per cent.	1.76 per cent.
Malic acid in 100 ccm. juice	0.92 g.	0.53 g.

The most recent determinations come from Behrens[2]. He found in

100 ccm. of	Water	Invert sugar	Acid
Pressed juice of the normal apple	87.38 g.	5.05 g.	0.56 g.
Pressed juice of the partially glassy apple	88.06 g.	4.40 g.	0.47 g.

In agreement with my statements, the above figures show that the flesh of the glassy apple is considerably poorer in acid, dry substances and ash. The glassy appearance and the smaller size is explained by the fact that the intercellular spaces of the glassy part are filled with water and the cells are smaller.

Practical growers believe they have observed that the following varieties tend especially to the production of glassy fruits:—Zürich Transparent apple, Gloria mundi, white Astrachan and Virginia summer Rose apple. On an average, in the first year of bearing, the little trees were more disposed to the production of such fruits than in later years.

b. Changes in Production Due to Lack of Nitrogen.

Starvation Conditions in Cryptogams.

In reference to the parallelism of phenomena in lower and in more highly organized plants, an example may be cited first of all from the fungi.

[1] Aderhold, loc. cit., p. 8.

[2] Behrens, J., Bericht d. Grofsh. Bad. Landes-Versuchsanstalt Augustenburg i. J. 1904, p. 58. Karlsruhe 1905.

Fliorow[1] tested the effect of starvation on respiration in Mucor and *Psalliota campestris*. In Mucor, respiration immediately falls to a great extent because in this fungus there exists no storage of reserve stuffs in the mycelium. In the fruiting body of the basidiomycete, however, there is a great deal of reserve material and, for this reason, it is very independent of the nutritive substratum so that its respiration only falls very slowly with starvation. In regard to the exchange of the proteins, Fliorow concludes from experiments with *Amanita muscaria* that *the percentage of nitrogen as a whole increases during starvation chiefly* because the substances free from nutritive substratum so that its respiration only falls very slowly with startakes place, which is simultaneous with the periods of spore formation and ripening. A rapid decomposition of the protein follows at once.

To be sure, the production of carbon dioxid and the taking up of oxygen gradually decrease in the starvation of fungi, but in unequal proportions, as was observed by Purjewicz[2], with *Aspergillus niger.*

Prantl[3] has given very good experimental observations on the prothallia of ferns. His experience shows especially that, in the seeding of fern spores, the most diverse variations occur in the prothallia. Some of them have a tissue capable of developing further (meristem), while others lack it and therefore are "ameristic." Earlier investigations[4] had shown Prantl that the ameristic condition can occur with too small supply of air as with a scanty supply of water and indeed also of mineral substances[5]. The observation, that under the most favorable conditions of illumination, ameristic individuals appear when the prothallia grow too close, led to the experiment of testing directly the influence of the nitrogen supply. Spores of the rapidly germinating *Osmunda regalis* and of *Ceratopteris thalictroides* were sown on different nutrient solutions. It was thus shown that the spores, germinated in distilled water, produced ameristic prothallia. They formed surfaces of 15 to 25 cells of pretty uniform size and similar content. The chlorophyll grains were poor in starch. On the other hand, the prothallia grown in a nutrient solution, free from nitrogen, but otherwise normal, were distinguished by an extremely large starch content, but otherwise resembled the individuals grown in distilled water. Only the specimens grown in a nutrient solution with a nitrogen admixture (0.64 per cent. ammonium nitrate) were meristic. If specimens of meristic prothallia were transferred into a nutrient solution free from nitrogen, the meristem disappeared after 14 days, while the cells as a whole increased, had divided here and there and had been filled with starch. If, on the other hand, ameristic prothallia were placed in

1 Fliorow, A., Der Einflufs der Ernährung auf die Atmung der Pilze. Bot. Centralbl. 1901. Vol. 87, p. 274.

2 Purjewicz, K., Physiolog. Untersuch. über die Atmung der Pflanzen. cit. Bieder m. Centralbl. 1902, p. 180.

3 Prantl, Beobachtungen über die Ernährung der Farnprothallien und die Verteilung der Sexualorgane. Bot. Zeit. 1881, p. 753.

4 Flora 1878, p. 499.

5 Reed has shown (Annals of Bot. 21; 501, 1907) that prothallia of G. sulphurea were unable to form archegonia where calcium was absent. Translator.

a complete nutrient solution, they at once formed a meristem on their outer edges by repeated cell-division, while the starch supply decreased.

The *distribution of the sexual organs* varies according to the nutritive conditions. Ameristic prothallia bear only antheridia, never archegonia, which are associated with the presence of a meristem. Of special importance at this point is Prantl's observation that ameristic prothallia of Osmunda, which had borne isolated antheridia, developed abundant archegonia after nitrogen had been supplied; besides the archegonia, antheridia also appeared.

From these changes produced by the nutritive substances is explained without forcing the *tendency to "dioecia"* ascribed to some ferns by various authors; by Millardet[1] for Osmunda, by Bauke[2] for the Cyatheaceae and for Platycerium, and by Jonkmann[3] for the Marattiaceae.

H. Hoffman[4] cites further notes pertinent here; first of all, Von Hofmeister, who assumes that in Equisetum the prothallia produce decidedly more antheridia in the light and in a dry locality, i. e., bear more male plants since the prothallia are almost entirely dioecious.

Borodin found that germinating spores of *Allosurus Sagittatus* developed antheridia when placed in the dark.

THE PRODUCTION OF STERILE BLOSSOMS. (STERILITY.)

Sterile blossoms in phanerogams are due primarily to a lack of nitrogen. This may manifest itself in very different ways; as already mentioned in the blasting of grain, a sufficient supply of nitrogen may be present in the soil but as result of a prolonged, intense drought there is lacking the carrier, the water, to bring to a further normal development the already differentiated stamens and pistils. On the other hand there may be in heavy seeding a struggle for nitrogen in which the plants that earliest attain most vigorous vegetative development take the nutriment from the less vigorous ones. In a consideration of sterility there must further be taken into account the cases where the existing nutritive material is used up in some other way, so that a one-sided increase or decrease of a growth factor favors the vegetative utilization of the elaborated organic material to such an extent that nitrogen sufficient to mature the sexual organs is lacking. Finally it not infrequently happens that the material is abundantly used in the development of the lesser nitrogen requiring male organs and no longer suffices for the development of the ovary. The cases among phanerogams where starvation conditions induce blossom development are not in opposition to this view. Examples of this are found in our fruit trees, where diseased specimens with a pronounced decrease of shoot development *"bloom themselves to death."* In horticultural practice plants are purposely starved in order to attain flower production (*Kantua dependens,* Correa, etc.)

[1] Pringsheim's Jahrbücher, X, p. 97.
[2] Bot. Zeit. 1878, p. 757.
[3] Extrait des Actes du Congrès International. Amsterdam, 1877.
[4] Hoffmann, H., Zur Geschlechtsbestimmung. Bot. Zeit. 1871. Nos. 6 and 7.

Lovers of cacti sometimes pull their plants from the pots in winter and let them shrivel, so that they may bloom more freely. In this case nitrogen is not lacking but the scarcity of water causes the plants to make use of the elaborated food in flower production.

In treating of the bearing of sterile blossoms, due to insufficient water, Oberdieck[1] reports that, as a result of drought, the blossoms of large-flowered pansies drop prematurely while, with sufficient moisture, they develop the seed capsules. Double zinnias behave in the same way, likewise the red flax and often, indeed, *Phlox Drummondii.* Garden beans do not set so well in dry years. Raspberries and strawberries give small, poorly seeded fruits. In the case of the ever-flowering wood strawberry there is a degeneration with continued drought, making the plants resemble the *"Vierlander strawberries,"* since they no longer develop fertile blossoms. Zacharias[2] states that the latter variety of strawberries is one which is usually either staminate or pistillate, but rarely monoecious. He is of the opinion that pollination is incomplete where only a few staminate, so called "wild" plants, distinguished by their weaker growth, weaker runners and lower growing inflorescences with larger blossoms, are present on the fields. He emphasizes the fact that invariably few pistils develop, so that only a portion of the swollen receptacal is covered. We would lay the chief weight on the latter point and advise remedially a change of soil and variety. Zacharias recommends putting more staminate plants among the pistillate ones.

Phenomena similar to those in the Vierlander strawberry have been observed in the black currant[3]. The sterility is said to be caused neither by dryness nor by a shady position, but is ascribed by practical workers to a varietal peculiarity. Likewise complaints are made as to the scanty setting of fruit in the *Schattenmorelle* (shadow Amorelle cherry). The "Praktische Ratgeber" (Practical Adviser) advises *in grafting* the taking of scions only from the trees of that variety which experience has proved to bear well. We often meet with such indications of the inheritance of undesirable peculiarities.

Numerous statements may be found in regard to the increasing predominance of staminate over pistillate blossoms. One of the earliest is the statement by Knight, that melons and cucumbers at higher temperatures without sufficient light almost always produce only stamens. Manz[4], in his experiments, comes to the conclusion that in monoecious as well as in dioecious plants drought favors the development of male plants, while moisture and good fertilization favor female plants. It is said that male plants can be made to bear perfect blossoms by removing whole branches. This might then indicate that the nitrogen taken up by the roots is now distributed among a lesser number of blossoms and thus better nourishes these.

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[1] Oberdieck, Deutschlands beste Obstsorten, p. 9 footnote. Leipzif, 1881.
[2] Zacharias, E., Über den mangelhaften Ertrag der Vierlander Erdbeeren. Verh. d. Naturw. Vereins, Hamburg, 1903. 3. Folge, XI, p. 26.
[3] Prakt. Ratgeber im Obst- und Gartenbau. Frankfurt a. O., 1904, No. 10.
[4] Vierte Beilage zur Flora, 1822, Vol. V (after Hoffmann loc. cit.), p. 88.

Conditions are similar with our fruit trees, most of which rest a year, that is to say, bear one year a smaller crop and then the next a larger one. After a heavy crop the trees are usually so exhausted that they need one year in order to store up sufficient nutritive substances for the next crop. Hoffman[1] mentions further that many trees (the horse chestnut and the Scotch Pine) exhibit a normal alternation of sexes, since they bear staminate flowers one year and perfect ones the following. The increase of carpels in the giant poppy (*Papaver somniferum* forma *polycarpica monstrosa*) occurs only in the most vigorous plants. During his travels Karsten[2] found that the palms growing in swamps and damp woods, as a rule, bear perfect blossoms, but become polygamous again from a lack of nutrition. The genera growing on dry cliffs or arid plains have ordinarily but not naturally separated sexes, and these bear staminate and pistillate flowers on separate branches. At the beginning of the dry season the fruit ripens, requiring a great deal of nutritive material, and then only staminate flowers develop; while after the dormant period, at the beginning of the rainy season, pistillate blossoms are formed in great abundance.

Cugini[3] found in starved plants of maize, which he obtained by heavy seeding, that various individuals bore only staminate flowers. De Vries[4] was also able to demonstrate the *inheritance of sterility* in the case of maize. He took seeds from plants in which the pistillate inflorescences were entirely wanting or extremely weak and obtained in the first year 12 per cent. of such imperfect plants. The sowing of the following year yielded 19 per cent. of sterile plants.

A case described by Müller-Thurgau[5] shows that aside from nitrogen hunger sterility can often be due to a lack of moisture alone. He found the stigmas on fruit trees so dry that the pollen grains could not germinate. In comparative test experiments with pears, trees which had been abundantly watered during the time of blossoming exhibited an evident increase in yield. Not only did numerous blossoms on the unwatered trees fall, shortly after the time of blossoming was past, but even the young fruits, when about the size of cherries, fell in strikingly large numbers. On trees standing in dry places, usually one fruit remained to each umbel, while in the case of watered trees, on an average, three developed.

But sterility occurs even with good pollen and with stigmatic conditions favorable for germination. Waite[6] in his experiments on pear blight kept insect visitors away from the flowers and found that the fruit set to a very small extent. Further investigations convinced him that certain varieties of pears and apples *cannot be fertilized at all* by their *own pollen* (nor by that from other individuals of the same variety), but that the pollen from an-

1 Bot. Zeit. 1882, p. 508.
2 Linnaea, 1857, p. 259.
3 Cugini, Intorno ad un anomalia della Zea Mays. cit. Bot. Centralbl. 1880, p. 1130.
4 de Vries, H., Steriele Mais als erfelijk Ras. Bot. Jarbook II, p. 109.
5 III. Jahresber. d. Versuchsstat. Wädensweil. Zürich, 1894, p. 56.
6 Cit. Galloway, B. T., Bemerkenswertes Auftreten einiger Pflanzenkrankheiten in Amerika. Zeitschr. f. Pflanzenkrankh. 1894, p. 172.

other variety was necessary for this. This would explain the observed sterility in large fruit orchards composed of a single variety.

Ewert[1] acknowledges that *self-sterility* has been determined for many species, but is of the opinion, nevertheless, that large plantations of only one variety do not fall behind those made up of mixed varieties, because cross-pollination will be secured promptly by honey and bumble bees. The setting of the fruit fails only if, because of unfavorable weather, the insects are unable to fly.

According to our theory there should also be noted in this connection the alternation between chasmogamic flowers (sterile with large petals), and cleistogamous flowers (fertile with aborted petals). With E. Loew[2], we perceive in these conditions no mutations in de Vries' sense, but simple variations which depend on the form of nutrition. Goebel found that cleistogamous flowers formed earlier and he was able, by keeping them dry and exposed to abundant sunshine, to force violets which had previously borne cleistogamous flowers, to form chasmogamic blossoms in July, which is a very unusual occurrence at that time of year. The alternation was called forth by the postponement of the use of the plastic food material at hand. The cleistogamous bud cannot develop with a lack of moisture and abundance of light and the plastic building materials then remain at the disposal of later produced blossoms. Since in these the pistils are rarely formed and do not mature, the material is free for the especially vigorous development of the petals which need the light.

Seedless Fruits.

Sterility is often connected with the appearance of seedless fruits, and can in the same way become a peculiarity of the variety.

In a new American variety of apples (the "Wonder of Horticulture") this charactistic has recently been considered an especial recommendation of the variety[3], since the blossoms yield fruit without having been fertilized. In this way, the harmful agents threatening other varieties at the time of blossoming, such as frost, mist, rain, drought, poor insect pollination, etc., are avoided. The new variety has no corolla and to this fact is attached the hope that blossom pests and other insects, which would be attracted by the petals, may spare such flowers.

Seedless varieties of fruits, i. e., those in which poorly matured seeds are found, have been known from the earliest times as, for example, the pear "Rihas Seedless," ("Rihas Kernlose") and the Seedless Father Apple ("Vaterapfel ohne Kern") It is said that it frequently happens that varieties free from seeds appear from grape seedlings, unfortunately distinguished, however, by their small size and the great hardness of the grapes.

1 Ewert, Welche Erfahrungen sind gemacht in bezug auf geringere Fruchtbarkeit, etc. Proskauer Obstbau-Zeitung, 1902.
2 Loew, E., Bemerkungen zu W. Burck's Abhandlung über die Mutation als Ursache der Kleistogamie. Biol. Centralbl. XXVI, 1906, Nos. 5-7.
3 Janson, A., Der kernlose Apfel. Gartenflora, 1905, p. 490.

The production of seedless fruits is mentioned often in the more recent works. Kirchner[1], who also cites Waite's[2] observations, declares that typically and normally developed fruits are obtained only by crossing with the pollen of a different variety. The largest fruits are always produced by cross-pollination. Pears produced by self-pollination developed at times almost no seeds. The flowers exposed to the visits of bees, or artificially cross-pollinated, on the contrary, yielded fruit with abundant healthy seeds. Thus it would be advisable to grow a mixture of varieties.

In opposition to this theory, Ewert[3], even in his latest papers, holds to his point of view, advocating for practical reasons the cultivation of a single variety in blocks.

In regard to seedless grapes, we will refer to the investigations of Müller-Thurgau[4]. Ewert emphasizes, in reference to seed-bearing fruits that, for the setting of the fruit, the amount of organic material at the disposal of the individual blossoms is of especial importance. In various cases a better nutritive condition for the individual blossoms can be obtained artificially by ringing, since they vary in their development. The pistils are either greatly developed and project as much as one centimeter above the anthers (protogyny), or both sexual organs are equally long (homogany), or the pistils are shorter than the stamens (protandry). Ewert's experiments do not confirm absolutely the conclusion that the stronger protogny is developed, the more the blossom, which is consequently self-sterile, demands the pollen of some other variety, and, conversely, the more homogany and protandry manifest themselves, the greater the possibility of self-pollination. It is evident that the organic nutriment is carried first of all to those fruit buds, in which cross-pollination has made seed formation possible. In comparing fruits containing seeds and those without seeds on the same tree, the seedless ones are smaller and are often malformed. If seedless fruits alone are produced on a tree, by keeping away all foreign pollen, they attain the same size as do those bearing seeds. Probably fruits can also be produced without the action of pollen.

In some cases fruits can be observed in which the core does not exist, or is scarcely indicated. In reference to the former, Burbidge[5] reports that pears without seeds and core represent very solid parenchymatous fruits, said to be larger, better flavored and possessing a better keeping quality than pears containing seeds.

I, myself, some years ago, received a branch of pears, one specimen of which is given half-size in Fig. 36. The fruits were perfectly hard and

1 Kirchner, O., Das Blühen und die Befruchtung der Obstbäume. Vortrag. Ref. Zeitschr. f. Pflanzenkrankh. 1900, p. 297.
2 Waite, Merton B., The pollination of the pear flowers. Washington, 1894, U. S. Dept. Agric. Bull. 5.
3 Ewert, Blütenbiologie und Tragbarkeit unserer Obstbäume. Landwirtsch. Jahrbücher, 1906, p. 259.
4 Müller-Thurgau, Folgen der Bestäubung bei Obst- und Rebenblüten VIII. Ber. d. Züricher Bot. Ges. 1900-1903.
5 Royal Horticultural Society of London. Cit. Bot. Centralbl. 1881. Vol. VIII, p. 319.

healthy until injured by the autumn frosts. At *A* we see a normal woody branch; at *B* a branch, the terminal bud of which is swollen up to a seedless fruit; at *C* is shown a fruit grown from a lateral bud with primordia of core; *n* is the scar of a fallen leaf; *s* an undeveloped lateral bud; *k* a perfectly matured leaf bud on the fruit stem; *sch* scale-like leaf on this stem; at *g* are the normally extended vascular bundle fibres, arranged about the compartments of the core (*f*) enclosing the rudimentary ovules. At *c* are visible the dried remains of the calyx and at *st* the branches of the style.

This case differs from the one described by Burbidge and from most others described as yet, in that the fruit is the product of the buds of the current, not of the previous year. It is not rare for the pear to bear occasional fall flowers. They can, in fact, arise from buds set the previous year, as is often stated, but, as yet, I have had opportunity to observe only such blossoms as were produced on the branches of the current year, matured in the summer, a fact which could be determined easily from the wood ring of the branch bearing the fruit. The proleptic blossoms had, with the relatively scanty nutritive supply and the short time granted them for development in the fall, naturally little opportunity to develop the parts of the cortex into well flavored fruit flesh. This explains, on the one hand, the lack of size and, on the other, the lack of flavor of the pears here described. If the fruit buds had not been stimulated by the unusually increased supply of water at the then autumnal season, they would probably have yielded perfectly normal fruits the following year.

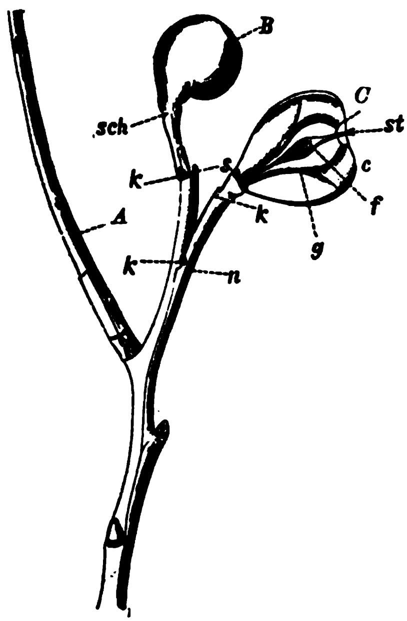

Fig. 36. Seedless Pear.

While the fruit remained seedless in this case, because in the proleptic development the accumulated building materials are insufficient, other cases also occur in which enough material is present, but is utilized in some other way because of the destruction of the normal embryo. Thus Müller-Thurgau[1] states that pears whose carpel layers had been destroyed by a late frost, produced fruit then exhibiting in place of a core a hollow chamber in which tissue excrescences had grown out from the side wall.

The appearance of seedless fruits is, therefore, to be treated primarily as a question of food supply. The organic building substances are not

[1] Müller-Thurgau, H., Eigentümliche Frostschäden an Obstbäumen und Reben. X-XII. Jahresb. der Deutsch-schweizer. Versuchsstat. Wädensweil, 1902, p. 66.

sufficient to nourish the embryo, no matter whether this arises from a failure of the stimulus of fertilization, from the poor position of the various blossoms, from the exhaustion of the tree as a result of a previous heavy crop, or from a proleptic development of a fruit bud. In consideration of the fact that seed-containing fruits develop better than seedless fruits from the same tree, it is more advisable agriculturally and horticulturally, as long as seedless varieties cannot be cultivated with absolute certainty, to encourage the possibility of seed formation.

Even if Ewert has proved that although in orchards of one variety the number of seedless and poorly seeded fruit is large, the fruits producing seeds still predominate, on which account he has asserted that *"pure planting"* is advisable, yet for the present we would give preference to mixed planting. The practical disadvantages in regard to the protection and harvesting of varieties growing and ripening differently may be decreased by cultivating each variety in rows. In avenues of trees at all times that variety which is most nearly ripe should be especially watched.

The Behavior of Weak Seeds.

The causes, which have affected the failure, or the poor maturing of the seeds in seedless fruits, have been felt more or less in other cultivated plants, so that we must also consider the behavior of poorly developed seeds. The scanty amount of nutriment must manifest itself in the specific gravity and, in this connection, Clark's[1] experiments show that *seeds of low specific gravity* do not germinate at all while those somewhat heavier germinate sparsely and often produce weak plants. The highest percentage of germination is found in seeds with the highest specific gravity.

According to Hosaeus'[2] experiments, normal plants can be produced even from immature, i. e. specifically light, seeds by carefully providing very favorable conditions. But the death rate is considerably larger in comparison with that of normal seeds. This refers especially to the use of grain, for example, which had necessarily been harvested in the *milk stage*. Sometimes the immature seeds undergo a sufficient subsequent ripening, outside of their fruit covering, and can then, under certain circumstances, germinate more quickly than the incompletely matured ones. According to Kinzel[3] this may occur in parasites of *silk varieties* (Cuscata) and is very well worth consideration in combatting them.

At times, with a poor quality of seed, a careful soaking is beneficial in order to shorten as much as possible the time the seed lies in the soil before its germination. Immature seeds especially decay much more quickly, particularly in heavy soils. But this soaking of the seed is disadvantageous because the seed must lie longer in the soil ungerminated if a period of

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[1] Clark, A., Seed selection according to specific gravity. New York Exper. Stat. Bull. 256. 1904.
[2] Deutsche Landwirtsch. Presse, 1875, No. 4.
[3] Kinzel, W., Über die Keiming halbreifer und reifer Samen der Gattung Cuscuta. Landwirtsch. Versuchsstat. 1900. Vol. 54, p. 125.

drought occurs, than if it had been sown naturally. Zawodny[1] has proved this experimentally for cucumbers. In this connection reference must be made to the already discussed interruption of germination by drought.

Dropping of the Fruit.

Besides the dropping of pears already mentioned, which Müller-Thurgau observed as the result of drought at the time of blossoming, fruit-bearing trees have an annual house cleaning during which poorly nourished blossoms or young fruits are dropped. The flowers developing last at the tips of the inflorescences, especially those at the ends of branches, are the ones cast off. There is not enough plastic nutriment at hand for development. The fruits nearest to the source of supply, the trunk axis, take up the nutritive substances at the expense of the organs further out. For fruits cultivated on trellises, these nutritive relations can be regulated artificially, since a large part of the unfavorably placed specimens can be removed with shears soon after the fruit is set.

In growing fruit for market very exact consideration must be given the moisture requirement, especially that of peaches and apricots. When the stone begins to harden, the most water is needed, and the dropping is often caused by a single dry period. Before and after this stage of development, however, more care must be used in watering, since otherwise sprouts are produced too early, which divert the material necessary for the maturing of the fruit. Then, at a later stage, the fruit will drop from a lack of nutriment, or, at least, be injured by it.

We have already mentioned in previous chapters that mature fruits may drop because of a late dry period, and it is now necessary to recall that fruit, injured by a late spring frost, is sometimes found in great quantity on the ground. All causes which lead to the *sudden lost of function* of an organ ultimately effect its dropping.

The Drying of the Inflorescences on Decorative Plants.

This phenomenon is often met with especially by amateur growers of potted plants. Aside from the effect of dry air which will be treated later, and the dryness of the soil already mentioned, there are two circumstances that come under consideration here. Both represent a starving of the blossom buds. In one case it is actually a lack of nitrogen which manifests itself when the plants stay in the pots too long, in the other case it is a lack of food for the blossoming organs, since other organs have taken it.

Our azaleas and camellias serve as the most usual example of the latter case. Plant lovers complain very frequently that the plants which have a great many buds do not open their buds in the house. In azaleas the buds become dry, in camellias they fall. In both cases fresh, rapidly and vigorously growing shoots develop prematurely directly under the blossom buds.

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[1] Zawodny, J., Keimung der Znaimer Gurke. Cit. Bot. Jahresber. 1901. Part II, p. 236.

In this premature breaking forth of the young branches lies the cause of the "fall of the blossoms." The error in treatment is that the plants are kept too warm and moist and insufficiently lighted for the given stage of their development. While the flower, to be sure, needs warmth and atmospheric humidity for its development, too great moisture in the soil injures it. This incites the leaf buds near the blossoms to a premature exfoliation and these attract the current of nutritive substances to themselves, squeezing out the functionally weak blossom buds.

In forcing bulbs, especially tulips, we also find such conditions of starvation of a flower bud resulting from too vigorous a development of the vegetative organs. In the newer cultivated varieties we often find that the flower stalk is not leafless, but has one or two leaves borne on clearly marked nodes. In such examples, the bud is so weak that, when forced in winter, it cannot develop at all, but dries up, because of preponderating leaf growth, resulting from the excess of moisture and warmth.

An experiment made with *Veltheimia glauca* may be cited as an example of the drying up of the flower buds, due to a lack of nitrogen. A vigorous double bulb had been divided several years previously and each daughter bulb had bloomed regularly every winter after this division. When later one of the bulbs was not transplanted, while the other was set in new, rich earth, the inflorescence developed earlier in the former, to be sure, and was more slender, but the flowers dried up before being completely formed. This plant was now given hornshavings as a source of nitrogen, without changing the soil in the pot. In the following year the inflorescence appeared to be more vigorous and the flowers more numerous; part of them developed and became colored, but not so deeply as those from the bulb which had been transplanted each year.

It is well known that a supply of nitrogen will increase the product of agricultural plants.

The Formation of Thorns.

The formation of thorns, i. e., the replacing of a bud on the end of a shoot by a woody, pricking tip, may be perceived as an indication of the lack of nitrogen. A comparison of figures 37 and 38 (cross-sections of *Rhamnus cathartica*) shows what changes have taken place. The tissues, indicated in both figures by the same letters, should be compared. We see that in the formation of thorns, the thick-walled elements gain the upper hand, and that even the parenchyma cells of the bark and of the pith have unusually thick walls. A young branch ending in a thorn, can at times form lateral buds at its base, if enough nitrogen is still present for the formation of the meristematic centers. But these lateral axes begin to assume thorn-like characteristics early in their development. Ducts may be found as far along on the thorns as leaf buds can be recognized and even for a distance beyond them. These usually disappear in the apical region.

The elimination of thorns is especially desirable horticulturally because, for example, the thorns of such plants as Crataegus, *Pirus communis,*

Prunus spinosa, etc., are very apt to injure people working among them. The transformation of the thorns into normal leafy shoots, ending with a terminal bud, results from pruning and transplanting the wild plants to rich, loose, well drained soils.

c. Changes in Production due to a Lack of Potassium.

By way of introduction, reference must be made once more to the fact that a lack of potassium in the soil conditions a lack of moisture. Hollrung's[1] recent experiments have proved that a soil mixed with potassium salts contains much more moisture than the same soil under otherwise similar conditions.

The potassium enters the plant in the form of potassium nitrate, sulfate and phosphate, chlorid or even silicate. In the plant it may be found in combination with organic and inorganic salts and especially in the tissues in which carbo-hydrates may be found. Hellriegel and Wilfarth proved experimentally that the amount of carbo-hydrates deposited as reserve substances (starch and sugar) in potatoes, grain and sugar beets, depends directly on the amount of potassium supplied. Thus it is evident that a lack of potassium must manifest

[1] Hollrung. Vortrag im Anhaltinischen Zweigverein für Zuckerrübenkultur. Blätter f. Zuckerrübenbau 1905 p. 76.

Fig. 37. Cross-section through a one-year old branch of Rhamnus cathartica.

a Cuticula. *b* Epidermis. *c* Cork layer. *d* Phellogen (cork cambium). *e* Collenchyma. *f* and *f'* Bark parenchyma. *g* and *g'* Bast bundles. *h* Secondary bark. *i* Wood, and on its periphery, the cambial zone. *k* Pith, *m* pith disc. (After Dobner-Nobbe)

itself in a scarcity of the reserve substances. Besides this, the lack of potassium explains also the fact, already observed, that shoot formation is retarded, since the cellulose, necessary for the formation of the parenchyma, is likewise a carbo-hydrate.

Without potassium, the plant becomes green, to be sure, but does not grow much beyond the amount of material furnished from the seed. All other nutritive material, therefore, can not have been used (law of the minimum). According to Nobbe's studies, if the very valuable compound, potassium chlorid, was given to potassium hungry plants, even after they had lain dormant for months, an increase in growth was produced in two or three days. *The formation of starch* began immediately[1]. An addition of potassium becomes fully effective, however, only when it is not rendered inactive by calcium. Ad. Meyer[2] emphasizes the especially favorable action of potassium chlorid, but he found this considerably weakened when calcium bi-phosphate was also present. With sugar beets potassium chlorid, as well as calcium chlorid, when used alone, worked very well, but not if added simultaneously.

Fig. 38. Cross-section through the thorn of Rhamnus cathartica.

Explanation of letters as in Fig. 37, only here the phellogen (*d*) and secondary bark (*h*) are lacking. They appear transformed into permanent cells. (After Dobner-Nobbe)

Hellriegel found in grain that with a scanty potassium supply, the green parts matured at the expense of the kernels. This is not the case with a lack of nitrogen; the plants then develop completely but remain small. In trees a continued lack of potassium always leads to a weaker development of the end shoots and finally to *"tip blight"* and Janson[3] states that he has cured this disease by a direct addition of 40 per cent. potassium salt. Naturally tip blight can be produced by very different causes, and on loamy soils especially other causes must often be sought primarily.

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[1] Nobbe, Schröder and Erdmann, Die organische Leistung des Kaliums in der Pflanze. Landwirtsch. Versuchsstat. XIII p. 321.

[2] Jahresber. f. Agrik. Chemie 1880 p. 269.

[3] Janson, A., Kalidüngung gegen die Spitzendürre. Prakt. Ratg. f. Obst- und Gartenbau 1905 No. 38.

Agriculturally worth consideration is the fact, confirmed experimentally[1], that with a lack of potassium, as contrasted with complete nutrition, a larger part of the nutritive substances taken up (excepting the phosphoric acid) will wander back into the soil at the time of ripening. This was observed, at least, in summer wheat, barley, peas, and mustard. Potatoes formed an exception.

The manifestation of a lack of potassium in fungi is very interesting. Molliard and Coupin[2] found in *Sterigmatocystis nigra* a malformation of the conidia which were produced only very exceptionally and matured incompletely. As under other conditions due to starvation, the conidia germinated at once, but their contents grew into a chlamydospore form.

The most important question for agriculture is, whether positive external characteristics may be found which indicate with certainty the lack of potassium?

We owe the most important experiments along this line to Wilfarth and Wimmer[3], who set up comparative cultures of sugar beets, potatoes buckwheat etc. They tested also for *scarcity of nitrogen* and *phosphoric acid* and found that with a lack of nitrogen leaves took on a light green to yellowish coloration and finally dried up with a light brownish yellow color. With a lack of phosphoric acid they were colored a deep, dark green, corresponding to the occasional excess of nitrogen, and in extreme cases blackish brown spots were formed at the edges and later distributed over the entire surface of the leaf, which sometimes had a reddish color at first. Finally followed a drying up accompanied by a dark green to a blackish brown coloration. If, however, sufficient potassium lay at the disposal of such starved plants, abundant quantities of starch and sugar were formed in spite of this; even with a lack of nitrogen, this process seems to be increased rather than decreased. If, however, in an otherwise normal nutritive supply, the potassium is lacking, the above-mentioned increased formation of straw in grain as against the formation of kernels becomes manifest. Under these conditions the amount of green growth in edible roots, or tuberous plants, was increased in proportion to the containers of the reserve substances, which possessed appreciably less carbo-hydrates than with a lack of nitrogen and phosphoric acid.

Since the plants use first of all the potassium supply in building their vegetative skeleton, they retain longer, by their habit of growth, the appearance of normally nourished plants with a lack of potassium than with a lack of nitrogen and phosphoric acid, but then the internodes are shortened and the leaves curl upward convexly. At first near the leaf edges and then later scattered over the whole surface of the leaf, appear yellowish spots which rapidly turn brown or often change to white, while the petioles and

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[1] Wilfarth, Römer and Wimmer, Über die Nährstoffaufnahme der Pflanzen in verschiedenen Zeiten ihres Wachstums. cit. Centralbl. f. Agrik.-Chemie 1906 p. 263.

[2] Molliard et Coupin, Sur les formes teratologiques du Sterigmatocystis nigra privé de Potassium. Compt. rend. 1903. CXXXVI p. 1659.

[3] Wilfarth, H. W. and Wimmer, G. (Ref.) Die Kennzeichen des Kalimangels an den Blättern der Pflanzen. Zeitschr. f. Pflanzenkrankh. 1903 p. 82.

veins together with the immediately adjacent tissue remain green. Finally the leaves dry up, beginning usually at the edges, with a dark brown color (see the adjoining Fig. 39). Flower and fruit formation are scanty. With a lack of potassium, not infrequently, individual plants go to pieces *prematurely*[1], while, with a lack of nitrogen and phosphoric acid, even the smallest plants can be maintained until the end of the time of growth.

Of especial importance is the observation of the above-named authors, that the roots as well as the tubers of plants grown with a lack of potassium tend very easily to decay and that plants lacking any nutritive substance are always *more predisposed* to attack from animal and vegetable parasites.

Von Feilitzen[2] made the same observation on timothy grown on moors. It was attacked by fungi only after it had been weakened by a lack of potassium. He noticed in clover that the lots sown without potassium, or with a slowly soluble compound of it, were "scorched" as if grown on poor sandy soil, after long periods of drought.

When experimenting with different fertilizers, Möller found that with a lack of potassium the seedling plants of the Scotch pine had less growing power, their needles had a faded appearance.

Valuable as are these attempts to find positive characteristics due to a lack of potassium, I still think that for a long time we will have to make use of these characteristics only with great care in diagnosis. In the first place, we do not know whether the same characteristics always,—i. e. with all variations of the factors of growth,—become visible in the same species. In the second place, we still know too little of the phenomena of starvation which make themselves felt with other nutritive substances. In the third place, the influence of injurious gases at times gives such deceivingly similar effects, aside from parasitic attacks, that it might be difficult to draw definite conclusions from the changes in habit alone. It should be taken into consideration that almost all injuries to the leaf manifest themselves first in the regions lying farthest away from the veins conducting water, hence the frequent beginning of the diseased condition at the edge of the leaf or in the middle of the intercostal areas, upcurved between the larger veins.

d. Changes Due to a Lack of Calcium.

It is well known that the plant uses calcium as stiffening for the cell walls and as a means for combining the poisonous oxalic acid produced. In the phenomena of disease, the fact that an excess of oxalic acid can re-dissolve small amounts of calcium oxalate is important[3]. The calcium oxalate produced is re-dissolved only in a few cases[4]. Usually the organism

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[1] Compare also, v. Seelhorst, Die durch Kalimangel bei Vietsbohnen (**Phaseolus vulgaris nanus**) hervorgerufenen Erscheinungen. Zeitschr. f. Pflanzenkr. 1906, p. 2.
[2] v. Feilitzen-Jönköping, Wie zeigt sich der Kalimangel bei Klee und Timotheegras? Mitt. d. Ver. z. Förd d. Moorkultur. 1904. No. 4. p. 41.
[3] Würtz, Dictionaire de chimie II, p. 647, cit. by de Vries in Landwirtsch. Jahrb. 1881 p. 81.
[4] Sorauer, P., Berträge zur Keimungsgeschichte der Kartoffelknolle. Berlin. Weigandt & Hempel. 1868, p. 27, and de Vries, H., Über die Bedeutung der Kalkablagerungen in den Pflanzen. Landwirtsch. Jahrb. v. Thiel, 1881, p. 80.

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Fig. 29. Lack of potassium.

1, Deformed tobacco leaf, resulting from a lack of potassium, with partially split, brown edges, only the veins are still green while the intercostal fields appear discolored yellow to white; *2*, Leaf of a normally nourished potato plant, *3*, that of one starving for potassium In this the leaflets stand closer to one another and are curled under The places drawn in light are yellowish, the intercostal fields are flecked with brown, as also the edges of the leaves; *4* and *5*, leaves of the buckwheat plant with spots which are yellowish, then brown, and finally white. (After WILFARTH and WIMMER).

does not possess the ability of re-dissolving the calcium already deposited in old tissues in appreciable amounts and transporting it where it can instantly become effective for new structures, when there is a lack of calcium. At least the experiments of Böhm[1], Raumer and Kellermann[2] and Benecke[3] prove that no calcium, or very little passes from the containers of reserve substances into the young tissues when the plants are grown in distilled water, in solutions free from calcium, or in quartz sand. The fact that no calcium is necessary for the formation of starch itself has been proved by Böhm. He found that primordial leaves free from starch with shrivelled petioles became filled with starch when grown without lime, but under otherwise favorable conditions. In order to dissolve the reserve substance and to transport it chemical combination with calcium is necessary, for an investigation of plants grown in media lacking calcium proved that the organs (leaves, cotyledons) had not given up all the starch, the leaf body or the adjacent internodes retained considerable quantities, while the young plant starved to death despite its sugar content. My own experiments[4] also led to the conclusion that the plant needs *new* mineral substances originating from the solution in the soil, even at a time when it is working up the reserve material into cellulose, etc.

Thus in the germination of seeds an addition of calcium acts beneficially; in fact, it often seems necessary. The statement that calcium is disadvantageous for germinating seed[5] may have arisen from a use of too highly concentrated solutions. Loew and May declare that definite excess of calcium in the soil over the magnesium content can produce starvation symptoms in the plant (see Lack of Magnesium). An earlier assertion of Dehérain and Breal[6] that, with a lack of calcium the plants can better utilize the lime stored in their bodies, if the temperature is raised, has not held[7]. Molisch, as well as Portheim, has also proved the error of these statements[8].

Among the older observers[9], Nobbe describes the phenomena due to a lack of calcium in water cultures. Buckwheat, peas, Robinia, etc., grew but little beyond the germinating stage. The pale leaves exhibited spots, similar to those produced by the action of acid, which dried up gradually, and then the petioles often broke. On conifers, the tips of the first year needles became yellow to brown.

1 Böhm, Über den vegetabilischen Nährwert der Kalksalze. Sitzungsber, d. k. Akad. d. Wissensch., Vol. 71, 1875, p. 287 ff.
2 v. Raumer and Kellermann, Über die Funktion des Kalks im Leben der Pflanze, Landwirtsch. Versuchsstationen XXV, 1880, Parts 1 and 2.
3 Benecke, W., Über Oxalsäurebildung in grünen Pflanzen. Bot. Zeit. 1903, Part 5.
4 Sorauer, Studien über Verdunstung. Forsch. auf d. Geibiete d. Agrikulturphysik, 1880, p. 429.
5 Windisch, R., Über die Einwirkung des Kalkhydrates auf die Keimung. Landwirtsch. Versuchsstationen. 1900, p. 283.
6 Annales agronomiques, Vol. IX, 1883, No. 52.
7 Krüger, W., und Schneidewind, W., Zersetzungen und Umsetzungen von Stickstoffverbildungen im Boden durch niedere Organismen, etc. Landwirtsch Jahrbücher, 1901, p. 633ff.
8 v. Portheim, L., Über die Notwendigkeit des Kalkes für Keimlinge. etc. Cit. Bot. Jahresber. 1901, Section II, p. 141.
9 Döbner-Nobbe, Botanik für Forstmänner. 1882, p. 314.

Recent cultural experiments with grain, buckwheat and *Elodea canadensis*[1] in nutrient solutions, free from calcium, showed that after a five day retention in a solution free from calcium, the root growth became less and later ceased entirely. The roots turned brown and the root cap died. Peculiar, brownish spots were found on the leaves, which soon went to pieces. The content in acid potassium oxalate and in starch was greater than in normal plants. The death of plants, in a nutrient solution without calcium, has been traced by Loew to a poisonous action of the magnesium salt. Bruch's cultural experiments with magnesium sulfate, nitrate, carbonate, and phosphate in aqueous solutions showed that the roots, to be sure, soon stopped growing, but the aërial parts developed further perfectly normally and even blossomed. Wheat plants in solutions free from calcium and magnesium died far more quickly than those in solutions lacking only the calcium.

Amar[2] observed the absence of calcium oxalate crystals in those leaves which were formed after the plants had been put in a solution free from calcium.

A further insight into the conditions due to a lack of calcium is given by Krüger and Schneidewind through Schimper's statement that, when the calcium is removed, all the symptoms of *poisoning* from an enormously large content of acid potassium oxalate are indicated. In Phaseolus these authors, to be sure, could prove no especial increase of a strong organic acid. They succeeded, however, in keeping the plants until all the reserve substances had been used up by painting dying seedlings with a calcium solution either on the hypocotyles or at the place where death usually begins. This substantiates Böhm's observations that seedlings of the scarlet-runner bean take up calcium as well as water through the outer skin of the petioles and leaves.

The experiments of Moisescu[3] confirm the above observations. He found in different cultures in nutrient solutions that those seedlings had became affected earliest and most extensively which had grown in solutions free from calcium. In *Platanus orientalis*, the leaves of which partially became brown and dry along the veins, it was found that the diseased ones contained twice as much acid as the healthy ones. *Gloeosporium nervisequum* infested the diseased leaves. On this account it must be assumed that the parasite named attacks only weakened leaves. This weakness would consist here of "*Calcipenuria*," that is to say, a lack of calcium. In the author's opinion, not enough calcium was present to convert the excessive potassium oxalate into calcium oxalate.

Besides cultural experiments of this nature, a large number of practical results point to the injuriousness of calcium poverty. At least we find in many cases a cessation of the phenomena of disease after an addition of

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1 Bruch, P., Zur physiologischen Bedeutung des Calciums in der Pflanze. Landwirtsch. Jahrb. 1901. Suppl. III. p. 127.

2 Amar, Maxime, Sur le rôle de l'oxalate de calcium dans la nutrition des végétaux. Annal. sc. nat. bot. 1904. XIX. p. 195.

3 Moisescu, N., Ein Fall von Calcipenuria. Zeitschr. f. Pflanzenkr. 1905, p. 21.

calcium. In this, the calcium may often act beneficially on the constitution of the soil and often directly on the composition of the cell sap. According to our explanation of the matter, a considerable number of cases of disease exist which are called forth directly by nitrogen excess, and for which the addition of calcium and phosphoric acid remains the only effective remedy. In the division "Enzymatic Diseases," we will also have to consider the beneficial action of calcium fertilization. There we will also touch upon the subject of the over-abundant formation of acid in the plant which certainly sometimes influences unfavorably the mode of production. Thus, for example, with a lack of calcium in the soil, the sap of *sugar cane* contains a great deal of acid and but little sugar[1]. We will mention later special cases of oxalic acid poisoning.

e. Changes Due to a Lack of Magnesium.

Plants grown in a nutrient solution lacking magnesium often live longer than when the nutrient solution does not contain calcium. It might be concluded from this that the plant is able more easily to remobilize the magnesium compounds already deposited in its tissues and to make them partially accessible again for the young organs. If the grain becomes diseased slowly from magnesium hunger, the leaves are a light green and appear limp, but not directly wilted. From the beginning it is possible to imagine a very considerable effect on the formation of seeds, if one considers that, for example, the globoids enclosed in the protein grains may be assumed to be calcium and magnesium compounds of a double phosphoric acid. In reality, with a lack of magnesium, there is a decrease in the formation of fruit, as stated by Nobbe[2]. He gives the following symptoms. The leaves become pale in color, with yellow to orange red spots here and there. The chlorophyll grains are pale yellow green and contain, as a rule, small amounts of starch. Diminished cell division is noticeable in the epidermis. Nobbe found that plants grown with a lack of magnesium correspond to those from nutrient solutions free from nitrogen, in that red spots are present on the petioles and the leaves fall prematurely. The latter characteristic may well be present in all starved plants, since the young organs exhaust the older ones when the supply of nutriment is insufficient.

Möller[3] also observed an orange red coloring in his cultivations of Scotch pine seedlings with a lack of magnesium. He says that the needles in October had bright orange yellow tips but farther back passed through a bright red zone into a normal green one. The discoloration appeared when the seedlings had been given magnesium in the second year. Ramann analyzed the orange tipped needles of two-year old Scotch pines and found that these contained 0.2791 per cent. magnesium (calculated on the dry weight), while the adjacent normally green specimens showed a content of 0.6069 per cent.

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1 Semler, Tropische Agrikultur. II Edition. Vol. III, p. 236.
2 Döbner's Botanik für Forstmänner, edited by Nobbe. 4th Edition, p. 315.
3 Möller, A., Karenzerscheinungen bei der Kiefer. Sond. Z. f. Forst- und Jagdwesen, 1904, p. 745.

In regard to the action of magnesia, Loew and May[1] have expressed the opinion that a definite quantitative proportion between soluble calcium and magnesium compounds is necessary for favorable growth (corresponding approximately to their molecular weights, i. e. 5 to 4). Magnesium in the soil in great excess over calcium is injurious. Plants which in so far lack magnesium, as that calcium is present in excess, exhibit symptoms of starvation. A small excess of calcium arrests the poisonous action of the magnesium. In the use of fertilizers containing magnesium, calcium should also be given at the same time. This advice should be taken to heart. Even if plants can well endure magnesium, and even actually need it, any excess is certainly injurious, as has also often been proved in fertilization with raw potassium salts.

f. Changes Due to a Lack of Chlorine.

It should perhaps be assumed that chlorine and calcium are antagonistic in plants. Mayer's conclusion, mentioned under potassium, that the action of potassium chlorid is weakened by calcium and, conversely, would indicate this. In the same way Knop[2] found that less calcium is taken up when the nutrient solution contains chlorine, and the calcium did not appear to be represented in any corresponding way by potassium or any other base. Thus the chlorine compounds (by the retention of the calcium) cause an essential increase in the acid content of the plant sap. Since, among the acids absorbed, the phosphoric acid predominates, Knop thinks it permissible to ascribe to this acid the greater fertility with a use of nutrient solutions containing chlorine, which was observed by Nobbe. Accordingly one would like to explain the process thus,—the chlorine which accumulates[3] in greatly different quantities in the plant body, according to the amounts offered the roots, can increase the transportability of the phosphoric acid, since it decreases the absorption of calcium and thus prevents the appearance of the phosphoric acid in the slowly soluble form of calcium phosphate. If the phosphoric acid, co-operating in the formation of the proteins, reaches very easily the meristematic areas of the growing tips, an abundant formation of cytoplasm occurs together with cell increase and, in connection with this, a plenteous streaming of the carbo-hydrates for the protein regeneration. Accordingly, vigorously growing shoots with but *little stored up reserve substances* will necessarily be found in plants, fertilized with chlorine. Actually, the many fertilization experiments show a decrease in starch and reserve sugar in the luxuriantly growing cultivated plants.

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[1] Loew, O., and May, W., The relation of lime and magnesia to plant growth. U. S. Department of Agric. Bull. I. cit. Bot. Jahresber. 1901. II p. 141.

[2] Chemisch-physiologiscne Untersuchungen über die Ernährung der Pflanze von Knop and Dworzak. Aus Berichte d. Kgl. sächs. Gesellsch. d. Wissensch. vom 23. April, 1875. Cit. Jahresber. f. Agrikulturchemie, 1875. p. 267.

[3] Pagnoul, Sur le rôle exercé par les sels alcalin sur la végétation de la betterave et de la pomme de terre. Compt. Rend. 1875. Vol. LXXX, p. 1010. Fertilizing experiments carried on for five years with chlorids showed for beets a fluctuation in contents from 1 to 50. In potatoes, the smallest yield in tubers coincided with the least amount of potassium carbonate in the ash but with the greatest amount of chlorides.

Besides the probable increase in the transportability of the phosphoric acid, it can be proved that chlorine has a favorable influence on the transference of the starch prepared in the leaves. According to Nobbe's experiments, the plant starving for chlorine continues to grow, exhibits a very dark green color and gives a considerable production of substances rich in carbohydrates, but sooner or later,—at any rate before the time of blossoming,—there occurs a peculiar change in form and structure. Nobbe found the dark, abnormally fleshy leaves crammed full of starch (in oak and buckwheat) rolling up, becoming brittle and dropping. The stems and petioles seem puffed up, the internodes of the stems always are shorter and many finally dry from the tips backward. If the plant reaches the blossoming stage, only scattered, unusually poor small fruits develop, despite the abundant starch material in the leaves. The effect of a lack of chlorine is best recognized by a comparison of a normal buckwheat plant with one grown with a lack of chlorine (figures 40 and 41).

Fig. 40. Blossoming buckwheat plant grown in a normal nutrient solution. (After Nobbe.)

g. Lack of Iron and "Jaundice" (Icterus).

The expressions, *"jaundice," "yellow-sickness, "white-leavedness," "variegation,"*

"chlorosis," "albication," "etiolation," are the most common names for the condition in which a leaf loses its green coloring matter in spots, or over the whole extent of its surface. The causes for this change in color are very different, but always represent a condition of weakness.

In order to survey the manifold causes of the disease, we will endeavor to group them into

1. Induced and non-transmissible conditions.
   (a). The discoloration attacks the whole surface of the leaf, which has matured in the light. After having been green in its young stages, the whole leaf assumes a yellowish, yellow to yellow-white color tone. *Icterus* or *jaundice*. Cause: usually a lack of nutritive substances.
   (b). The pale discoloration is present in the young organ and the leaves remain in a condition resembling youth until their premature end. Cause: lack of light and at times of heat (see these topics).
2. Innate and transmissible conditions. Portions of the plant show yellow to pure white spots or stripes. Those plants suffer especially in which pure white leaves appear near the ones spotted with green or all green. The spots have usually a sharp demarcation. *White-leavedness, albication, variegation*, sometimes transmissible through seeds or by grafting. Cause: probably enzymatic disturbances (see these).

Fig. 41. Buckwheat plant grown in a solution free from chlorine. (After Nobbe.)

Of course there are intermediate stages between the types named, since the individual causes often work together.

In the present division we will examine only the icteric conditions and treat them under lack of iron because, since the investigations of the Gris[1], father and son, it is customary to consider jaundice as caused especially by

[1] Gris, A., Ann. scienc. nat., 1875, VI ser. Vol. VII, p. 201.

a lack of iron. The authors named found jaundiced leaves turning green where painted with a soluble iron salt. A change to green may also be observed if the roots of such plants have a dilute iron solution at their disposal. The experiments on the effectiveness of the iron solution were often repeated; as, for example, by Knop[1] and Sachs[2], who observed in cultures of maize in nutrient solutions free from iron, that the plants remained green only as long as the reserve material from the seeds lasted. After this time, leaves developed which were green only at the tip and were already yellow at the base, until the next leaves appeared uniformly icteric. Similar discolorations, at first appearing in stripes, were found on mature plants which had developed normally at first, and then were placed in a nutrient solution free from iron. The blossoms then became sterile and the production in dry weight was considerably less. Frank[3] observed that there occurred with a lack of iron an universally noticeable phenomenon of starvation, viz., the newly produced leaves exhausted the older ones, which lost their color and died. In icteric organs, the chlorophyll grains have a normal form, but their number and size is possibly smaller and their color pale. Although the chlorophyll pigment contains no iron[4], the whole nutritive condition of the chlorophyll grain will become weakened by the lack of iron. But at first the chloroplast exists in a normal form which is not destroyed until later. In this lies the difference between the phenomena of starvation and enzymatic albication.

In order not to be obliged to separate the phenomena whose similar symptoms lead to confusion, we will mention here *icterus due to cold.* We find in cold, wet seasons a gradual yellowing in most cultivated plants, which disappears of itself with a rise in temperature. Often in spring, the leaf points of our flowering bulbs are yellow when they push out of the earth and the young leaves push out gradually with a normal green color only as the weather becomes warmer.

From this transitory jaundice must be distinguished the chronic form, in which the yellow leaves always remain yellow. This may be observed if sudden great cold affects the young cells and destroys the chloroplasts. Then, in place of these, are found only fine grained yellowish groups and at times also yellow drops. These cells do not recover later. At the place of transition to the parts of the leaves which, protected by the earth, have become green, colorless, swollen and also light green chlorophyll grains which later partly turn green may be found at the place of transition to the portions of the leaf, which, protected by the earth, have become green.

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1 Knop (Jahresberichte f. Agriculturchemie, 1868-69, p. 288) observed in such experiments that the iron which got into the plant could not be proved in the cell sap, and, therefore, must be present in a combined form. In 1860 (Bot. Z. p. 357), Weiss and Wiesner determined that iron occurs only in insoluble compounds and in the contents of the older cells as well as in their walls.

2 Experimentalphysiologie, p. 144.

3 Krankheiten der Pflanzen. 1895, I, p. 290.

4 Molisch, Die Pflanzen in ihren Beziehungen zum Eisen. 1892, p. 81.

With the action of sudden cold, lasting for several hours, Haberlandt[1] found that a noticeable change occurred at a temperature of minus 4 to 6 degrees C. and only at minus 12 to 15 degrees C. does the destruction of the chlorophyll grains become complete (with the exception of those in evergreen plants). With the formation of vacuoles there was produced a *distortion of the form* of the chloroplasts which were either passing over into the position along the side walls (apostrophe) or were rolled up in lumps. Of these the ones inclosing starch grains were destroyed more quickly than those without starch. In the leaves of *Vicia odorata* no difference could be perceived in the destruction of the chlorophyll, dependant upon the age of the leaf.

We will touch upon this subject again under autumn coloring. A yellow leaved condition in spring is found often in pears growing in nurseries, as the after effect of frost disturbances.

The grape is very susceptible to *icteris.* Different factors have been recognized here as the cause. In the cases observed by Mach and Kürmann[2] in the Tyrolean vineyards, the analyses of green and icteric vines, growing close together, showed:

Water Content of the yellow leaves......77.97 per cent.
Water Content of the green leaves......73.17 per cent.

Based on dry weight, the green leaves possessed a higher percentage of organic substances and of nitrogen, but considerably less ash. The ash of the yellow leaves contained six times as much of the elements insoluble in hydrochloric acid as did that of the green leaves. On the other hand, there was less potassium in the former. Watering with liquid stable manure acted beneficially. A similar case is described by E. Schultz[3]. The leaves and woody portion of the diseased vines contained only half as much potassium as those of the healthy plants, which were found, however, to be poorer in calcium and magnesium. Besides this icterus due to a *lack of potassium,* a jaundice of the grape, resulting from an *excess of calcium,* has been determined by numerous observations. It seems to me that the amount of calcium in itself is not the injurious factor, but chiefly the lack of potassium, since calcium soils, as a rule, are poor in potassium. We will return to this case in the section on the excess of calcium.

Nitrogen starvation is also a frequent cause. This, differing from the phenomena due to a lack of other nutritive substances, does not manifest itself in the death of the plant in an early stage but only retards the growth and reduces all the organs to a minimum.

The oft repeated experiments with the cultivation of non-leguminous plants in nutrient mixtures without the addition of nitrogen have shown that under otherwise favorable conditions, with certain races, a new min-

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[1] Haberlandt, Über den Einfluss des Frostes auf die Chlorophyllkörner. Österr. Bot. Zeit. Cit. Jahresbericht, 1876, p. 718.
[2] Biedermann's Centralbl. 1877, p. 58.
[3] Zeitschr. d. landwirtsch. Centralver. für das Grossherzogtum Hessen. cit. Centralbl. f. Agrikulturchem. 1872, p. 99.

iature plant can be produced from a seed, developing even to the production of a few blossoms and new seeds. The entire nitrogen content of the whole plant, however, does not in this case equal that of the original seed. It is evident from this fact, firstly, that the plant is not in a condition to make use through its leaves of the nitrogen from the air in quantities worth mentioning; secondly, however, we perceive that nitrogenous substance stored up in the seed enables various individuals to run through their whole developmental cycles, that is to say, to perform all the life-processes, in a minimum compass. This demonstrates further that the nitrogen stored in the seeds is easily mobilizable and *capable of transportation,* indeed, that the same molecule may probably be utilized more than once for the same purpose in the construction of the cell cytoplasm. A consideration of the growth of plants, with a lack of nitrogen, indicates such a condition, for it is found that the lowermost leaves are exhausted to the amount of growth of the tip of the stem and begin to dry, beginning at the edge, or at the tip.

In the rapid convertibility and capacity for transportation of the nitrogen a lack of this nutritive substance occurs very rapidly and manifests itself in jaundice. In our cultures such cases can also occur, if the supply of nitrogen in the soil is still abundant but not in a form available for the special requirements of the definite plant under cultivation. The best example is found in our sugar beets, to which, besides stable manure, nitrogen is given chiefly in the form of *Chile saltpetre.* The frequent, very favorable results of fertilizing various other cultivated plants with ammonium sulfate have now led to the use of this fertilizer in beet culture. But in a practical way these results have not been satisfactory, since the polarization of the beets was far from normal.

In a thorough discussion of this point Hollrung[1], Krüger and Schneidewind emphasize that the sugar beet is a pronounced nitrate plant, but since the ammonia is not converted so rapidly and directly to nitric acid by the micro-organisms of the soil, a lack of nitrogen compounds may occur and the beets suffer although enough nitrogen is present as ammonia. The phenomena of a yellow leaved condition may be due to the constitution of the nitrogen fertilizer which is unsuited to beets, although it may be suitable for grain and potatoes.

An older note has already pointed to the difference in effect secured according to the form of nitrogen provided. Analyses by Lagrauge[2] showed that in beets fertilized with ammonium sulfate, twice as great an ammonia content was demonstrable as in those fertilized with sodium nitrate.

It is a well-known fact that a yellow color can be caused in beet leaves by *drought* alone, so that we need to cite only a very characteristic example. In 1896 (according to Troude[3]), the beets in France, especially in the northern part, suffered extensively from a yellow leaved condition. The

[1] Hollrung, Inwieweit ist eine Düngung mit schwefelsaurem Ammoniak geeignet, bei den Zuckerrüben eine Schädigung hervorzurufen? Vortrag. Blätter für Zuckerrübenbau, 1906, p. 70.
[2] Biedermann's Centralbl. 1876. I, p. 258.
[3] Cit. Zeitschr. f. Pflanzenkrankh. 1897, p. 55.

phenomenon appeared in June after a longer period of intense drought and became widespread especially in sunny positions and on light soils, while regions with a damp, sea climate showed the disease only slightly. The sugar content of the slowly growing beet was from 2 to 3 per cent. less than that of healthy specimens.

By a survey of the individual cases just cited, we are led to the conviction that icterus is one of the most widespread symptoms of disturbed assimilation. No conclusion as to any definite cause has been furnished as yet, however, in the occurrence of jaundice.

h. Changes Due to a Lack of Phosphorus and Sulfur.

The distribution of phosphorus in the various parts of the plant, determined earlier by Ritthausen's macro-chemical studies, was proved later micro-chemically by Lilienfeld and Monti, as well as by Pollacci[1]. The last found that, in general, the cell walls are free from phosphorus while the proptoplasm, and especially the nucleus, with the chromatin bodies, contain this element in abundance. Among the aleurone bodies the crystalloides and globoids likewise contain phosphorus. The proteins depend especially on the amount of phosphoric acid at hand and a lack of it will make itself felt especially in the blossom buds and in the maturing of the seed. According to Nobbe's cultural experiments[2], phosphorus does not seem to play any part in the formation of the chlorophyll pigment;—the foliage of oaks which had stood for three years in nutrient solutions, free from phosphoric acid, was still green. In other plants Nobbe ultimately observed that a deep orange red color appears in the leaves and petioles. There is no production of any new dry substance, or only a small amount. Möller[3] observed in the needles of his pine seedlings a blue-red (dull violet) color due to a lack of phosphoric acid. In two-year old plants the violet color tended more to olive brown.

In the reports on discoloration phenomena, which set in with a lack of various nutritive substances, the results obtained with one plant species cannot be applied to a different species, since discoloration is not everywhere the same. In regard to phosphoric acid, I found that when plants of beets, peas, and seradella were grown without phosphoric acid they dried a gray green when they had previously been a faded green, but not yellow, while, with a lack of nitrogen, the same species turned a pure quince yellow.

Nobbe found a somewhat better development with a lack of sulfur in the nutrient solution, yet his experimental plants scarcely attained half the normal height and the yellowish green leaf blades exhibited a correspondingly scanty development. The starch was scanty and small grained. Cell division was considerably impaired. The forming of fruit either did not take place, or only very scantily.

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1 Pollacci, G., Sulla distribuzione del fosforo nei tessuti vegetali. Malpighia. Vol. VIII. Cit. Zeitschr. f. Pflanzenkrankh. 1895, p. 299.

2 Döbner-Nobbe, Botanik für Forstmänner. 4th Ed., p. 317.

3 Karenzerscheinungen etc. Zeitschr. f. Forst- u. Jagdwesen, 1904, p. 745

i. Changes Due to a Lack of Oxygen.

General Phenomena.

It is to be assumed as well known that, with the cessation of the supply of oxygen, the protoplasmic currents gradually come to a standstill (*oxygen rigor.*) Kühne[1] observed that in an atmosphere of hydrogen the motion in the stamen hairs of *Tradescantia virginica* stopped after 15 to 20 minutes. Wortmann[2] found that the parts of plants in air free from oxygen respired at first exactly as much carbon-dioxid as those with an unimpaired supply. Later a difference made itself felt in favor of the latter plants. Like the gradual cessation of the cytoplasmic currents, this gradual retrogression in the amount of carbon-dioxid with the exclusion of oxygen (*intramolecular respiration*) indicates that the oxygen stored in the plant body is consumed at first. *Death from suffocation,* therefore, takes place slowly, especially since the green plant with sufficient illumination still decomposes carbon-dioxid and water and thus forms oxygen for some time. Böhm[3] detected a small amount of oxygen in the volume of gas evolved when he enclosed the green leaves of land plants in an atmosphere of hydrogen with sufficient illumination.

Aside from the cases which have been observed already in the divisions on "Loamy soils" and "Too deep planting of trees," we will consider a few occurrences of bad aëration as a result of closing the lumina of the ducts forming the main water system. Such stoppage is especially serious for the sap wood[4]. With Böhm[5] we may picture to ourselves the process of aëration as follows: There is not only a difference in pressure between the outer air and the diluted air inside the ducts, but also a difference in constituents. The enclosed air will give up its oxygen in the respiratory processes more rapidly and take up the carbon-dioxid produced. This is either soaked up, by the filling of the ducts with water, and carried off in the rising sap current, or, since it penetrates the moist walls rather easily, is given out in a radial direction by diffusion. The new and necessary oxygen which in lesser amounts may also enter through the roots with the air rich in oxygen, dissolved in the water, will, nevertheless, under normal conditions get into the plant mainly through transverse conduction. It diffuses more easily through moist walls than does the nitrogen of the air, because water absorbs it more abundantly than it does nitrogen. Since now the oxygen within the plant body is utilized most but is also most easily capable of moving from part to part, there results a prevailing diffusion stream of oxygen from without inwards in each horizontal plane of a trunk.

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1 Untersuchungen über das Protoplasma. 1864, p. 89 and p. 106.

2 Wortmann, Über die Beziehungen der intramolekularen zur normalen Atmung. Inauguraldissertation, Würzburg, 1879.

3 Böhm, Über die Respiration von Landpflanzen. Sitzungsber. d. Kais. Akad. d. Wissensch. in Wien, Vol. 67 (1873).

4 Elfving, Über die Wasserleitung im Holze. Bot. Z. 1882, No. 42.

5 Böhm, J., Über die Zusammensetzung der in den Zellen und Gefäfsen des Holzes enthaltenen Luft. Landwirtsch. Versuchsstationen Vol. XXI, p. 373.

Wiesner[1] made further observations on *gas exchange.* He shows that the periderm, the cork covering, is completely impermeable to air even with great differences in pressure. The exchange takes place only through the lenticels which are permeable even in winter. In wood free from ducts the equalization takes place through the cell walls, especially through the delicate pitted walls in which, besides the diffusion, absorption through the colloidal walls comes into effect. In woody bodies, rich in ducts, transpiration and the penetration of gases through the ducts, functioning as capillary tubes, should also be taken into consideration. The equalization of the pressure takes place more quickly axially than transversely. The more turgid a parenchyma or wood cell is, the more slowly does the equalization of the pressure occur. This relation is reversed in the periderm cell. If it incurs the loss of its aqueous contents and is filled with air, whereby its wall becomes dry, the cell loses its permeability for gases. In parenchyma which conducts air, a part of the air flows through the intercellular passages during the equalization of the pressure, another part passes through the closed membranes and, indeed, most easily through the places which have remained unthickened.

A statement by Mangin[2] throws light on the processes taking place in trees, with poor soil aëration. He found that the ducts in Ailanthus were filled with tyloses, and, in explaining the process, states that, correlative with a lack of air in the soil, a deficiency in the supply of air in the ducts takes place. Consequently the air in the ducts becomes diluted beyond the optimum and the tyloses of the adjacent cells push into the tube of the duct and, on their part, also hinder the conducting of water.

In regard to the influence of a lack of oxygen on seeds, Bert's[3] investigations should be considered first of all, according to which germination progresses more slowly in a lesser air pressure. Many years ago Corti[4] observed that a *dilution of the air* had an arresting influence on the cytoplasmic currents. Since, however, with a normal air pressure and only decreased oxygen content, germination takes place more slowly and, conversely, with a lowered air pressure but increased supply of oxygen the seeds germinate more rapidly, it is evident that even the partial pressure of the oxygen alone is a decisive factor.

In the phenomena due to lack of oxygen, opportunity is again offered of pointing to the fact that *sudden changes are more disturbing than gradual changes.* Stich[5] found that in an atmosphere poor in oxygen the normal respiratory quotient is recovered by decreasing the absolute amounts of oxy-

1 Wiesner, Versuch über den Ausgleich des Gasdruckes in den Geweben der Pflanzen. Sitz. d. Kais. Akad. d. Wissensch. zu Wien am 17 April, cit. in Oesterr. Bot. Zeit. 1879, p. 202.

2 Mangin, Influence de la raréfaction produite dans la tige sur la formation des thylles gommeuses. Compt. rend, 1901, II, p. 305.

3 Bert, Recherches expérimentales sur l'influence que les changements dans la pression barométrique exercent sur les phénomènes de la vie. Compt. rend LXXVI et LXXVII.

4 Meyen, Pflanzenphysiologie, 1838, II, p. 224.

5 Stich, C., Die Atmung der Pflanzen bei verminderter Sauerstoffspannung und bei Verletzungen. Flora, 1891, p. 1.

gen and carbon-dioxid. With a gradual removal of oxygen, intramolecular respiration is aroused only with a considerably lower percentage of oxygen, than it is when the oxygen is suddenly decreased.

The discovery that phenomena of suffocation occur also in seeds if their tissue is entirely filled with water is of great value to the practical worker. Usually when seeds are soaked they get the water necessary for germination without having all the air pressed out of the intercellular spaces. If, however, the seeds are kept too long in water, decomposition sets in, in which often a distinct ordor of butyric acid, a result of bacterial decay, becomes very evident. In the same way experiments, like those of Just[1], for example, show that when air has been removed by a pump from the tissues ordinarily containing air and the space filled with water, the percentage of germination is very greatly reduced.

When seeds have been put in layers on top of each other while damp, it is not the excess of water, which so quickly destroys the germinating power, but the excessive heating and formation of carbon-dioxid. Wiesner[2] found also that the carbon-dioxid is developed later than the heat. Hence its development is not the only source of heat; this is to be sought also in the absorption of water. The seed, coming in contact with water, condenses it as it enters the tissues and thereby frees heat.

That *an excess of oxygen* is just as injurious as a lack of it, is natural. Bert found that the oxidizing processes in plants are arrested by too high a tension of the oxygen. A mimosa died at 6 atmospheres in common air, having lost its irritability because of a lack of oxygen. If the air was made richer in oxygen, a pressure of 2 atmospheres was sufficient to cause death.

The Brusone Disease of Rice.

The unusually dreaded brusone disease which manifests itself by the appearance of rusty spots in the leaves together with a blackening and drooping of the blades, has often been the subject of earnest study, ever since Garovaglio in 1874 began investigating it. The majority of investigators considered the phenomenon parasitic. Some thought it necessary to assume bacteria to be its cause, and some held various fungi responsible,—among others, *Piricularia Oryzae* Br. et Cav.

Recently, however, Brizi[3] has made comparative cultural experiments from which it becomes evident that an exclusion of air from the roots in high temperatures in water cultures induces disease of the plants with the phenomena of the Brusone disease. With these experimental results agree very well the discoveries which have been made in Italy and Japan. It has been especially observed that the Brusone disease usually appears if compact, only slightly pervious soils are heated greatly and a rapid change of temperature sets in. There then follows an affection of the root which

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1 Bot. Z. 1880, p. 143.

2 Landwirtsch. Versuchsstationen, 1872, No. 2, p. 133.

3 Brizi, U., Ricerche sulla malatti del riso detta Brusone. Ann. Instituto agrar. Ponti. 1905. Milano. Cit. Zeitschr, f. Pflanzenkrankh. 1906.

brings disease of blades in its train and only later do parasitic organisms infest the diseased parts.

We consider Brizi's experiments as decisive and think that suffocation of the roots during high temperature, which greatly increases the leaf activity, is the first impulse to the disease. The soil should be aërated at once.

The Diseases of Gladioli.

A phenomenon of disease, not rare in cultivating gladioli in heavy soils, or on pieces of ground with a lighter soil, but a higher ground water level in wet years, may be traced to a lack of oxygen. The disease manifests itself in the often sudden death of the plant at a time when the inflorescence is already developed. At first the lower leaves seem marbled with yellow (noticeable at first only when the light falls through them). The chlorophyll bodies decompose and leave yellow drops which look like oil. While this process advances apparently in stripes between the veins in the aërial parts of the leaves, brown, depressed places are found on the leaf bases still below the soil which initiate a complete decomposition of the leaf parenchyma. No real weakening takes place, but the decomposition represents a process of humification. Bacteria, and often also fungi, small worms, mites, etc., are always found in these tissues which smell sour like humic acid. The aërial parts of the leaves dry quickly and become covered with black pits of Cladosporium and Alternaria.

Despite the wealth of parasitic organisms present, the disease should not be characterized as parasitic, since the first stages, viz., the brown coloring of the ducts and of the parenchyma, lying close to them, are produced within the healthy tissue without the co-operation of such organisms. Later a number of the duct tubes are filled with a cloudy, brown mass which becomes firm like gum. The latter phenomenon has been observed also in other plants, the roots of which were injured by continued moisture in the soil and the lack of oxygen thus produced artificially.

Gladioli like a great deal of moisture in the soil but it should not be long continued. In dry years the mistake is often made of watering bulbs and tuberous plants every day. This is wrong, the excessive drying of the soil must be prevented by mulching with litter.

k. Changes Due to a Lack of Carbon-Dioxid.

Despite the small content of possibly 0.036 to 0.040 volume per cent. of carbon-dioxid, which the air[1] possesses, while consisting of nearly 79 parts of nitrogen and 21 parts of oxygen, it suffices everywhere for a high rate of growth; if this important nutrient substance is entirely lacking, the other factors of growth are without value, even in a most favorable combination, as may be observed experimentally by placing vessels of caustic

[1] According to Jolly's investigations (cit. in Forsch. a. d. Gebiete der Agrikulturphysik. 1879, p. 325) the oxygen content of the air varies not inconsiderably (between 20.53 and 20.86 per cent.). The largest oxygen content is found with a prevailing polar current and the least with a prevailing equatorial current.

potash under closed bell-jars. Corenwinder[1] found that buds and young leaves do not develop further in air free from carbon-dioxid. In Boussignault's[2] experiments two maize kernels developed into plants of which the dry weight itself and the carbon and oxygen contents were less than in the seed, while the nitrogen content was just as large. Hydrogen and ash had undergone a slight increase. Bohm[3] found in leaves of the scarlet runner bean, cut off from the plant during growth, from which the starch had been removed by darkness, that these leaves not only formed roots from the petioles in full daylight and in an atmosphere containing carbon-dioxid, but also increased in breadth even if they were watered only with distilled water. On the other hand the seedlings of the scarlet runner bean grown in distilled water and exposed to the action of full daylight under bell-jars with caustic potash showed only an increase in length up to 10 cm. while the stems shrivelled below the primordial leaves which as a rule were free from starch. Seedlings of the scarlet-runner bean which had been grown in garden soil rich in humus but were robbed of all but a small amount of their starch by weak illumination, did not form any new starch but went to pieces when later strongly illuminated in an atmosphere robbed of its carbon-dioxid. Therefore, the carbon-dioxid in the soil and the other favorable conditions for growing were of no value. Godlewski[4] found that the starch also disappeared in plants exposed to full daylight if the carbon-dioxid of the air was kept from them.

A further insight into the method of growth of plants from which the carbon-dioxid of the air had been removed is given by my own experiments[5]. Young cabbage plants were left in a 0.5 per cent. nutrient solution, part under bell-jars with caustic potash, part under others without caustic potash and the remainder left free between the bell-jars. After ten days the harvest yielded:—

	Uncovered plants				Bell-jars with Potash		Bell-jars without Potash		
Plant No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Fresh weight of root and stem	0.457	0.367	0.414	0.470	0.175	0.2305	0.297	0.313	0.232
Fresh weight of leaves	1.598	1.494	1.564	1.682	0.765	1.011	1.736	1.712	1.850
Upper leaf surface in square cm.	50.6	47.5	50.1	47.3	25.4	26.6	50.4	54.1	37.1
Total dry weight	0.2755	0.2510	02.685	0.2760	0.0760	0.0985	0.1705	0.1740	0.1765
Percentage of the fresh weight in dry weight	13.4	13.5	13.5	12.8	8.4	7.9	8.1	8.6	8.4
Total evaporation in grams	69.3	74.4	82.5	75.0	27.4	34.4	43.1	40.4	43.3
Evaporation per gram dry weight	251.5	296.4	307.2	271.7	360.6	349.2	252.8	232.2	245.3

The table shows that the production in fresh and dry weight was the smallest under the bell-jars with potash. The absolute amount of evapora-

1 Recherches chimiques sur la végétation. Fonctions des feuilles. Compt. rend. t. LXXXII, 1876, No. 20, p. 1159.

2 Boussingault, Végétation du Mays. commencé dans une atmosphère excempte d'acide carbonique. Compt. rend. Vol. LXXXII, No. 15, p. 788.

3 Böhm, in Sitzungsber. d. Wierner Akad. 1876, cit. Bot. Zeit. 1876. p. 808.

4 Bibliographische Berichte über die Publikationen der Akademie der Wissenschaften in Kraukau. Part I, cit. Bot. Zeit. 1876, p. 828.

5 Sorauer. Studien über Verdunstung. Forschungen auf dem Gebiete der Agrikulturphysik, Vol. III, Parts 4 and 5.

tion is greater or less according to the amount of newly produced dry substance; it is smallest in the plants under the bell-jars with potash. Naturally the effect of the bell-jars, i. e., the humidity prevailing under them, is to be taken into consideration. This factor manifests itself, when compared with the uncovered specimens, by the lower percentage of dry weight in the plants, i. e., by a loose structure and longer petioles.

If the specimens from the bell-jars containing potash are compared only with those of the other bell-jars, the result is more certain. The lack of carbon-dioxid manifests itself most by the lessened total production, especially in the leaf apparatus; the upper surface is only about half as large. The most striking effect is the amount of evaporation, which is calculated per gram of dry substance present. This is greatest in the plants deprived of the carbon-dioxid supply. The same condition is found in the calculation of the evaporation per square centimeter surface in the plants grown under both conditions. This fact should be associated with the results of other experiments, according to which it is evident *that the amount of evaporation increases also* in plants which *lack other nutritive substances.* If, for example, plants from a normal favorable nutrient solution are placed in one of too low concentration, or in distilled water, evaporation is increased; it increases also in seedlings after the removal of the organs containing reserve food, the cotyledons. It may be assumed that the plant must force itself to a greater transportation of water through its roots, i. e., to a greater one-sided kind of labor, in order to meet lesser amounts of reserve substances contained in the solution due to their increased absorption by the roots from the surrounding soil.

For practical work, the above investigations suggest an attempt to increase production by increasing the supply of carbon-dioxid. Experiments actually show that a much more rapid formation of starch is obtained by increasing the carbon-dioxid. In many plants an increase up to 6 to 8 per cent. was possible. Of course, a different absolute quantity of carbon-dioxid is necessary for each plant and in the same plant for every other combination of the vegetative factors in order to obtain an optimum production. The strengthening of the vegetative processes by the addition of carbon-dioxid manifests itself in the more compact growth and thicker leaves[1].

While previous experiments have taken up the results of a lack of carbon-dioxid for the whole plant, Vöchting[2] tested the behavior of various branches, which were left on the normally growing plant, but transferred to an atmosphere free from carbon-dioxid. It was found thereby that each branch and leaf must be maintained by its own work and that their life activity gradually dies away if this work is prevented by a lack of carbon dioxid. The plant can, indeed, develop further the branches in the atmosphere free from carbon-dioxid, but the leaves on these branches are a faded

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1 Feodoresco, E., Einfluss der Kohlensäure auf Form und Struktur der Pflanzen. Cit. Centralbl. f. Agrikulturchemie, 1900, p. 137.

2 Vöchting, H., Über die Abhängigkeit des Laubblattes von senier Assimilationstätigkeit. Bot. Zeit. 1891, Nos. 8 and 9.

green and form no starch. They also do not recover, if the branch is brought back to air containing carbon-dioxid, but go to pieces after a short time. It thus becomes evident that each leaf has its independent existence and that any disturbance of it cannot be adjusted by the organism as a whole. The organ which has become functionless is thrown off from the body.

B. EXCESS OF WATER AND NUTRITIVE SUBSTANCES.

a. Excess of Water.

MOISTURE.

The phenomena of yellowing and decomposition connected with stagnate water have been considered when discussing the disadvantages of heavy soils. We are thus concerned here only with proving by example, how an excess of water, like a lack of it, retards production. Thus Stahl-Schröeder's[1] experiments with oats in sterile sea-sand to which the nutrient solution had been added, gave the following results. With the addition of water there were produced:

% of the entire water capacity of the sand	No. of kernels	Weight of 1000 kernels g	Weight of straw and chaff g	Medium length of the plants cm.	Ash %	Phosphoric acid %	Nitrogen %
35	84	15.5 (calculated)	6.2	49	?	?	3.752
50	1723	21.6	73.9	102	2.933	1.444	2.915
70	2074	18.5	101.8	140	2.712	1.090	2.501
90	1827	16.3	115.0	157	3 007	1.207	2.407
95	469	11.1 (calculated)	90.8	162	5.892	1.847	3.444

Thus only the vessels containing a medium amount of water yielded a good harvest in grains. With a larger water content, the harvest of grains fell, while the yield in straw increased. With a lack of water in the sand (35 per cent.) and with an excess (95 per cent.) none of the grains ripened. The poorer the growth of the plants, the greater their percentage of ash content, and wealth of phosphoric acid and nitrogen.

Clogging of Drain Tile.

Wherever flat lying drains extend through the root systems of perennial plants, an unusually luxuriant root growth may stop up the drains. The long whip-like, very slender and comparatively thin roots lying side by side, like cords, in this way form mats ten or more meters long and as thick as the width of the drain allows. The most dangerous tree seems to be the willow for most of the drain mats seem to be formed by it, yet all plants may form similar root-growths and Magnus[2] once found, for example, the rhizome of the horse tail (*Equisetum palustre, L.*) growing very luxuriantly in such a mat. Cohn[3] found a drain mat which came from a pipe laid 125

1 cf. Biedermann's Centralbl. f. Agrikulturchem. 1905, Part 2.
2 Sitzungsber. d. Bot. Vereins vom 26 Mai, 1876. Vol. XVIII, p. 72.
3 Verh. d. schles, Gesellsch. f. vaterl. Kultur, 25 Oktober, 1883.

cm. deep and was formed entirely from the ramifications of the root of a single Equisetum from which a piece 12 meters long could be separated.

Müller-Thurgau experimented with roots from one plant, putting some in a nutrient solution, others in distilled water; each experiment showed a stronger growth in the solution. These experiments showed that root growth increases locally when the roots reach places containing food substances.

If the drain mats return after removal, it is advisable to take out carefully both trees and roots by uprooting and not by chopping down. If the trees must remain it is better (especially with double lines of drainage) to lower the surface laid pipes (as a rule between 80 to 90 cm.) to the level of the pipe system lying deeper (1.5 m.).

Sprouted Grain.

In the phenomena to be cited here which are connected with an excess of water, injury is caused either by the fact that water from outside acts mechanically on the tissues at an unsuitable time, or the water taken up by the roots cannot find utilization and be carried off in corresponding amounts. To the first group belongs grain sprouted on the field during the harvest because of rain. The disadvantage is the greater in this instance, since the sprouted kernels can neither be used for nutritive purposes nor are they suitable for seed. Of course the germinative capacity for subsequent use as seed decreases according to the amount the kernels have sprouted. Ehrhart[1] found that the weakness and thus the mortality of the seedlings increased as their development had already advanced because of the premature sprouting. We owe to Märcker and Kobus[2] thorough investigations of the changes in the seed due to sprouting. The former investigated barley, half of which was harvested uninjured, but the other half was left standing for almost 14 days, wet through by rain. The differences were shown by a determination of the elements soluble in water, for they amounted to the following in

	Sprouted	*and in well-harvested barley*
Soluble starch	1.17 per cent.	1.76 per cent.
Dextrin	0.00 per cent.	1.10 per cent.
Dextrose	4.92 per cent.	0.00 per cent.
Maltose	7.32 per cent.	3.12 per cent.
Other soluble substances	5.23 per cent.	5.64 per cent.
	18.64 per cent.	11.62 per cent.

We thus see that the vigorous diastase action has resulted in a very abundant sugar formation from the starch and dextrin. The starch content had fallen from 64.10 per cent. to 57.98 per cent., because of the sprouting. If the kernels are used for making starch, the great amount of

[1] Deutsche landwirtsch. Presse, 1881, No. 76.

[2] Aus Braunschweiger landw. Z., 1882, No. 22, cit. in Biedermann's Centralbl. f. Agrikulturchemie, 1883, p. 326.

diastase would now presumably convert more starch into dextrin and sugar, when softened, and result in appreciable losses in manufacture. The greatest changes due to sprouting, however, are found in the nitrogen-containing elements of the grain. While especially the ammonia content had remained unchanged (nitric acid was not found in quantities worth mentioning in either of the two kinds of grain) the soluble proteins had decreased to a great extent, the insoluble to a lesser one. This decrease is explained by the relatively great increase of the amides. Thus, in sprouting, first the soluble proteins had been consumed in the formation of the amides and later even a part of the insoluble ones.

Kobus arrived at the same results in his investigations of sprouted wheat, whose gluten content had decreased from 20 to 25 per cent. This fact explains the well-known loss in *baking quality* of a flour made from sprouted grain.

The germinating capacity in the experiments carried out by Märcker had fallen from 98 per cent. to 45 per cent.

It thus becomes evident how worth while are the great efforts which must be exerted in any case to make possible harvesting the grain while dry. Similar losses may befall other field crops as well, as, for example, lupines, rape, beet roots. The cases in which the seed germinates inside the fruit without being noticeable externally are interesting but not of importance agriculturally. I found such cases in pears, apples, melons, and pumpkins. Other observers found the same phenomena in oranges, as well as pumpkins, and indeed in other fruits also which had remained very long on the trees, and in that which had only colored late. Further statements on this subject may be found in the section on germination interrupted by drought.

The Rupturing of Fleshy Parts of Plants.

Fleshy roots, stems and fruits frequently crack open in long periods of dampness. Among vegetables, kohlrabi, carrots and parsley suffer especially. Hallier[1] proved that the rupturing is due to excessive water supply, for by hanging parsley roots in water he found after three days that all the part which was in the water had cracked open. Boussingault[2] observed the rupturing of cherries, mirabelle plums, pears, grapes, and blueberries after the fruits had hung in water. I obtained the same results by imbedding them in wet sand. Of herbaceous stems, those of rape crack open very freely shortly before the time of blossoming. The figure here given shows the change in a bean, which I had planted too deep in wet sand. In July, 1882, in Proskau, I found ruptured potato stems and *Beta vulgaris* roots. At that time a very rainy July had followed a dry spring after a small amount of winter moisture. The phenomenon was apparent at first on light places in the soil and in the best developed plants. I found similar cases in roses and in plum seedlings, which had been taken from the sand and

[1] Hallier, E., Phytopathologie, p. 87.
[2] Compare Bot. Jahresbericht, 1873, p. 253.

placed deeper in a nutrient solution than they had been in the sand. The base of the stem split in those specimens previously exposed to the air. In the souring of crops in fields planted with horse beans, peas, vetches, etc., the base of the stem is ruptured at times above the places where the (rotted) roots arise, and it is found that a spongy, loose tissue protrudes from the torn place, as in the bean here illustrated.

All these phenomena have one characteristic in common —that they are initiated only when, after a considerable period of normal development, or still more after a previous dry period, an unusual supply of water is given suddenly. If the plants are in contact with water from the beginning of their development, they adjust themselves to their surroundings. The same adjustment can be observed especially in those varieties which develop in water as well as on dry land. Levakoffski's[1] experiments on *Epilobium hirsutum*, *Lycopus europaeus* and Lythrum serve as examples. The comparison of water and land specimens shows that in the water plants, two rows of colorless

[1] Levakoffski. De l'influence de l'eau sur la croissance de la tige etc. Cit. Bot. Zeit. 1875, p. 696.

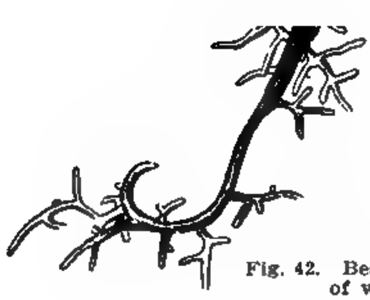

Fig. 42. Bean plant split at the base as the result of excess of water. The torn place has scarred over.

cells, free from chlorophyll, 3 to 4 times as long as they are broad, exist between the cambium and the bark parenchyma which are not present in the land specimens. This difference becomes greater, when the older parts of the plant are compared with one another. Below the surface of the water these cell rows become a thick, lacunar tissue Epidermis and bark soon go to pieces here. The cells which form this special tissue are developed from the cambium.

The *sudden excess* of water, which causes the rupturing of part of the plant, destroys the equilibrium in the epidermis, or the cork layer present instead of the epidermis, and in the fleshy parenchyma body. Especially after previous periods of drought, the elements of the upper epidermis become thicker walled and less elastic and are not able to accommodate themselves rapidly enough to the swelling inner tissue.

If the rupturing takes place in succulent organs without any previous dry period, due to a long continued supply of water in damp surroundings, the torn places, as a rule, differ from those due to drought, in that, in the latter, the wounded surface turns to cork or is cut off by a new cork layer. In the former, on the other hand, the parenchyma cells, exposed by the rupture, remain thin walled, at times elongated into pouches and decaying easily. Boussingault found that the fruits lost sugar to this excessive water. This loss of sugar together with the increased absorption of water may explain the *watery taste of the fruit* after rainy weather. Some blossoms, left under water, also lost sugar. On the other hand, in sugar beets, rape, in the seedling roots of wheat, barley and maize no sugar was lost although the tissue was rich in sugar.

There is a *method of storing winter apples* which is well worth recommending, viz., placing the fruit in layers in sand. If the sand is kept too moist, a large percentage of the fruit may lose in selling value because the skin ruptures.

Müller-Thurgau[1] made similar observations in related experiments. After apples had lain eight months in boxes of earth he found the fruit was wet, some of it ruptured, some mealy, and its acid and sugar content much lower. The percentage of decaying apples was much less, however, than in fruit lying free in the cellar.

The rupturing of fruits and vegetables, due to storage methods, can be overcome by supplying a dry, well ventilated place. In fruit on the tree, especially the egg plum which is very delicate, it is advisable in longer periods of rain to shake the water from the tops of the trees.

Finally, attention must still be called to the fact that the *tendency to rupture can also become hereditary*. An observation of this was made with cucumbers[2]. In forcing these, the owner always chose for his seed the finest specimens of a variety which ruptured easily, and observed that this bad condition manifested itself more abundantly and earlier from year to

1 Fünfter Jahresb. d. deutsch-schweizerischen Versuchsstation zu. Wädensweil. Zürich, 1896.
2 Zeitschr. f. Pflanzenkrankh. 1899, p. 183.

year. He then planted half of his greenhouse with the forcing variety previously used and the other half with an outdoor variety. The latter gave healthy fruit up to autumn, while the half planted with the first variety produced ruptured fruit from the beginning of May on. Such observations give hints well worth noticing when choosing seed of vegetables which tend to rupture.

THE WOOLLY STREAKS IN APPLE CORES.

In describing apple varieties the expression "The carpels of the cores rupture," is found stated here and there, as a characteristic of the variety. According to the illustration here given, a condition of membranous carpels is said to be indicated in which the inner walls of the core divisions are not uniformly smooth and solid, but show a surface crossed by streaks which

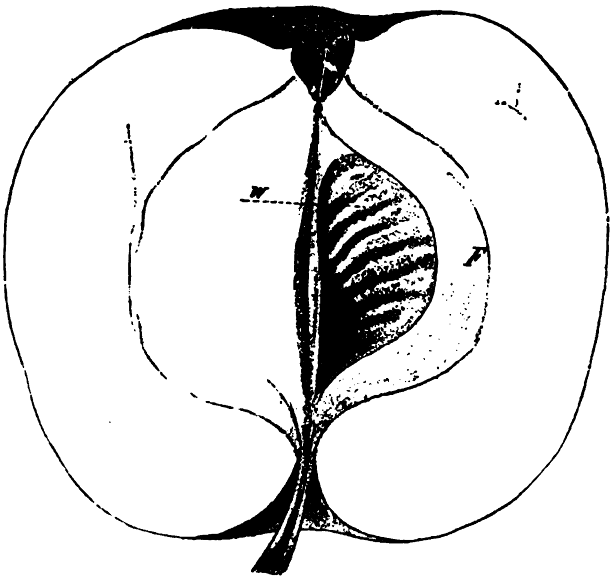

Fig. 43. Cut apple, the core of which shows woolly streaks (w).

look white and woolly, and extend slantingly from the centre to the outside. The phenomenon occurs frequently and is considered to be normal,—which deduction I do not care to hold to. Aside from the fact that under certain circumstances all the fruit in the same variety does not show such woolly streaks and that, in different years, it is developed to a different degree, even appearing in isolated cases in varieties which, as a rule, have a smooth core, the conditions found microscopically also prove splendidly the abnormal nature of these streaks.

If a carpel with such streaks is cut through, as shown in Fig. 43 at *w*, the appearance is found as given in Fig. 44. In this the side designated by *K* is the inner wall of the core, while *F* indicates the outer side bordering on the flesh of the fruit. In varieties of apples with smooth carpels, the inner lining of the core is formed only of such cell elements, as are shown

at p. These are very much elongated, extraordinarily thick-walled cells, traversed by many, frequently branched canals; they turn yellow with chloriodid of zinc. Single layers of such cells may cross one another. Accordingly, besides such cells seen in full length at p, the same horizontal section also exhibits parts of elements in cross-section q. It is evident that, because of the close arrangement of the cells on the one hand and because of their very strong walls on the other hand, a very great firmness is obtained in the core tissue, increased by the transverse course of the cells. It is evident further, that in fruits with a larger calyx depression, through which fungi may grow easily into the core, the spread of fungi, which produce decay, is limited by the parchment-like, solid carpels.

Fig. 44. Rupturing of the papery carpel of the apple, due to the excrescence tissue of a woolly streak. (Orig.)

This protection from internal decay is destroyed by the woolly streaks (Fig. 43 W) for they consist of very loose tissue, which breaks through the solid walls.

We see in Fig. 44 that these woolly streaks are formed of thick bunches of cell rows elongated like threads, which differ strikingly from the surrounding ones because of their thinner walls, and very gradually pass over into the tissue of the fruit (F), while others are quite sharply and suddenly cut off from the thick-walled cells (p) below the places in the core which have remained membranous. Only at the base of this bunch of threads do short, schlerenchymatous cells (sk), isolated or lying beside one another in mats, recall the elements (p) to be found in the normal wall. Although these

thin-walled cell rows approximate more nearly tissue of the fruit in form and by the blue coloration from chloriodid of zinc, they still do not correspond to it entirely. The difference consists chiefly in a wart-like thickening of the cell wall *w* which is most strongly developed in the outer cells of the thread bunch, but in the inner cells is often only weakly indicated and generally is not present at all in the schlerenchymatous elements. These cell wall thickenings which push outward and look like buttons, show, with the action of chloriodid of zinc either a pale blue color or remain uncolored, or even appear yellow. The latter case is found most distinctly in the very thick-walled cells (*sk*) in which the whole membrane is also colored yellow. Fig. 44, at the left, is a more strongly magnified section from a cell row of the bunch filament. It is seen here that the wart-like protuberances of the wall which I would also like to consider phenomena of the swelling of various points in a fine middle lamella, often have mushroom forms (*kn*)[1].

Thus it should be assumed, that at the time of the chief swelling of the fruit, the tension of the tissues in the carpel has become so great, because of a sudden, great supply of water, that the connection in the membranous tissues is broken in stripes and loosened and the elements now freed from pressure, and not thick-walled, extend like pouches into the hollow of the core.

Varieties inclined to have woolly streaks are especially easily exposed in damp years to the formation of moulds, i. e. phenomena of decay in the core. It is, therefore, advisable to use these fruits quickly.

The Ring Disease of Hyacinth Bulbs.

This disease is very serious for growers of hyacinth bulbs. It manifests itself by the browning and loosening up of a scale in the midst of healthy bulb layers. The decomposition of the tissue progresses from the neck of the bulb downwards into the bulb centre. If it reaches the latter, the bulb is as good as lost. The disease is often transmitted to the bulblets. All the diseased parts become covered with Penicillium, which here has actually taken on a parasitic character. The reason for the extremely rapid spread of the fungus is to be found in the change of the substratum which proves unusually favorable for it. Analyses show especially that the fresh, *healthy* substance of the ring-diseased bulb possesses more sugar than that of healthy specimens. The former resemble younger scales in contrast to the older ones. Since now a reduction of the sugar takes place with the increased ripeness of the bulbs, we shall have to conclude from the greater amount of sugar that diseased bulbs are less ripe.

In fact it may now be proved that by their cultural methods our bulb-growers often run the risk of harvesting unripe bulbs. In taking up the bulbs, the grower sometimes does not wait until the leaves have completely dried up in summer. This holds good primarily where the hyacinths serve

[1] The same or similar phenomena have been observed very recently by various scientists. I found them also in the hair-like cells, clothing the interior of beets which had become hollow; in the leaf parenchyma cells of fallen oat plants, etc.

as decorative plants in gardens and public places. There a bed of old flowers and slowly yellowing leaves is very unsightly. Consequently the bulbs are lifted and let ripen in another place. The resulting great injury to the root prematurely checks the vegetative growth of the bulbs. The leaves dry before they have lived out their life and their bases, i. e. the scales of the bulbs, remain immature and rich in sugar, thereby forming the desired centre for convenient infection by the fungus.

In the large field-grown commercial bulbs, the supply of fertilizer enters into the question, since it is desirable to produce very strong bulbs in the shortest possible time. The fertilizer so lengthens the time of growth that many varieties have not finished growth at the fixed time of harvest. The leaves, still green, then possess in every case unique scales and during the storage of the harvested bulbs on the "bulb floors," up to the time of the autumn sales, Penicillium has ample time to attack the scales, which remain rich in sugar, and to destroy them. It is a matter of course that varieties ripening especially late will exhibit this bad condition and the growers, therefore, speak of "ring diseased races."

The testing of the bulbs is accomplished by cutting superficially through the tip of the neck during the dormant period. If the cross-section shows a brown ring between the white scales of the bulbs, these bulbs should not be sold.

Stock suffering from the ring disease can be cured by putting the bulbs in sandy soils, not freshly manured, with a deep lying ground water level, where, with scarcity of nutriment and moisture, they can ripen early.

The fact still remains to be mentioned that a phenomenon has been confused with the real ring disease, which is very similar to it judging from its habit of growth[1]. The cause is known to be a nematode (*Tylenchus Hyacinthi* Pr.) which can wander into the scales from the leaves. In this disease, however, a gall-like distension of the cells takes place, also the formation of cork walls like little islands and other differences, as has been described more in detail in the second edition of our manual.

Springing of the Bark.

In illustrating the ruptured bean plant (Fig. 42), we noticed that a soft tissue mass had protruded through the gaping split in the cracked stem. This is the new formation of bark tissue, which may be considered a reaction of the organ to the wound stimulus and the decreased tension. Other cases, however, occur in which matters are reversed, viz., that the increase of bark tissue is the primary process and the splitting, the secondary one. Such an increase in growth can arise from different causes. Hartig[2] considers one of these to be the increase in size caused by a sudden *isolation of forest trees*. He describes cases of hornbeams in a beech grove, where,

[1] Journal de la Soc. nat. et centrale d'Horticulture de France. April, 1881. Sorauer, Zur Klärung der Frage über die Ringelkrankheit der Hyacinthen. Wiener illustrierte Gartenzeitung, 1882. April number, p. 177.

[2] Hartig, R., Das Zerspringen der Hainbuchenrinde nach plötzlicher Zuwachssteigerung. Untersuch. forstbot. Inst. Vol. III, p. 141.

after isolation,—"the breast high growth, measuring 1.2 sq. cm. in cross-section, in a few years increased in cross-section growth to 13.7 cm. annually[1]." The cork was split thereby in numerous places and resulted in a rupturing, indeed, in places it lifted the bark body from the wood-cylinder. Hartig found similar conditions in oaks and explained this by a greater soil activity, resulting from the isolation and increased action of light[2].

Phenomena of this kind may be found also in other trees, especially in parks and gardens.

Shedding of the Bark.

Hartig describes a case in which the splitting of the bark is due to an increase in the normal growth. I observed a splitting and shedding of the bark from an abnormal cell - elongation in the bark parenchyma. In 1904, I found in an avenue of elms a number of trees standing side by side at the bases of which a great many pieces were perhaps as long as one's hand. Upon closer investigation, loosely hanging strips of bark 25 to 50 cm. long were found on the lower end of the trunk, which could easily be removed. The trunk, thus exposed, was covered with greenish tissue in spots which proved to be new formations of bark. The loosened pieces of bark (Fig. 45), exhibited on the inner side flat, light brown cushions irregularly distributed and differing in size and thickness. Having a spongy consistency, they easily gave way to the pressure of a finger-nail. Here and there, between them could be seen crater-like, harder, small protuberences. The upper surface of the cushion was smooth; it was rough and sometimes woolly in places because of prominent, hair-like processes. The part of the bark remaining on the

Fig. 45. Inner surface of a fallen piece of elm bark, with cushion-like, protruding tissue islands. (Orig.)

[1] Lehrbuch der Pflanzenkrankh, 1900, p. 261.
[2] Unters. Vol. I, 1880, p. 45.

tree appeared a yellowish green and juicy. It consisted of bark parenchyma, which had originated from a healthy cambium.

The subjoined Fig. 46 pictures the bark about to be shed. At *h* is shown the old wood; at *nh* the last produced new wood; *g* indicates ducts; *c* the cambium. Next this lies the normal, young bark which gradually passes over towards the outside into the broken older bark. In reality the extent of loosened older bark is much greater in proportion to the normal young bark than is shown in the drawing, because of lack of space. The normal inner bark has a very regular structure, in which layers of porous bark parenchyma alternate regularly with flat bands of slender cells (*l*) which might be differentiated as *"wedge-cells"* These slender cell bands would correspond to the "pressure wedges" mentioned in connection with the tan disease. The cells forming these wedges appear in longitudinal section as long as in cross-section, nearly colorless, with peculiar, wide-meshed wall thickenings, looking like irregular wedges. The parenchyma lying between every two such thin, slender bands of wedge cells is proportionately large-celled, porous and rich in starch. Deposited in it are large, hard bast bundles, (*b*) with the rows of calcium oxalate crystals accompanying it (*o*) and the cells (*sl*) containing mucilage.

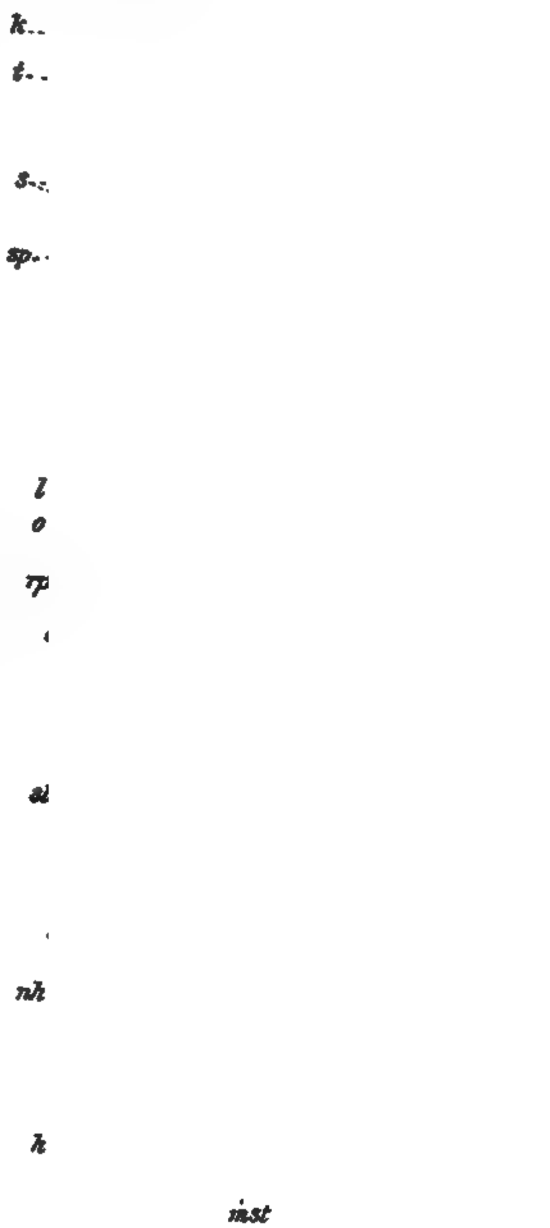

Fig. 46. Elm bark with bark excrescence. (Orig.)

These alternating tissue layers are separated by broad curved medullary rays *(mst)* which even in the entirely healthy bark can exhibit a wavy course, but in the diseased bark may often be displaced and take a horizontal course. The sharp curvature is caused by the spreading apart of the parenchyma cells which, containing chlorophyll and lying between the slender bands of wedge cells, elongate into pouches, and for a long time contain a great deal of starch. They also press outward the hard bast bundles and the rows of oxalate crystals. This great layer of separation is covered by a plate cork layer extending irregularly into the tissue and often accompanied by full cork (*t*) and the suberized bark tissue cut off by it which belonged to the earlier period of growth (*k*). The cork layer often curves spherically into the pouch-like spongy tissue (*sp*) and forms the hard, crater-like points on the under side of the loosened bark scale, which were mentioned at the beginning of this description. The process of loosening the bark tatters is completed on the boundary between the hard tissue of the suberized cortex of the previous year, and the soft pouch-like parenchyma. The upper surface of the separating cushions appears woolly and rough, or smooth, according to whether the pouch-like parenchyma clings more or less strongly to the separating surface.

In the elongation of the parenchyma these out-pushings differ from the tan disease in which cork excrescences are concerned essentially.

von Tubeuf[1] describes a case of the Weymuth pine very similar to that on Ulmus, only no shedding of the bark strips could be observed because of the smoothness of the bark. The pine was diseased and covered with cushions of *Xanthoria parietina.* Among these lichens were found blister-like processes, of which part appeared to be split and were produced by a distention of the bark tissue. The resin ducts were enlarged, the deeper bark parenchyma cells elongated into pouches and poor in chlorophyll.

von Tubeuf's statement that he had produced very similar knob-like processes on a branch by wrapping it with cotton wadding which was kept constantly moist, warrants the assumption that, in the cases above described, we perceive the action of a local excess of water.

The same kind of processes as these in the bark have been observed on roots also. Some years ago a serious disease of the grapevine was reported from near Lindau[2]. Its effects were similar to those caused by the rust fungus, but it could not be proved to be of parasitic origin. The part of the trunk beneath the soil and the older roots exhibited tears 1 to 3 cm. long from which protruded calluses, white at first but later turning a chocolate brown. The lateral roots near these calluses died. The calluses consisted of bark parenchyma cells abnormally lengthened radially and scarcely connected any longer. The American varieties, scattered among the diseased European vines, were found to be unaffected. As is well-

1 v. Tubeuf, Intumescenzenbildung der Baumrinde unter Flechten. Naturw. Zeitschr. f. Land- u. Forstwirtsch. 1906, p. 60.

2 Kellermann im Jahresber. d. Sonderausschusses f. Pflanzenschutz. Arb. d. Deutsch. Landw.-Ges. 1892-93.

known, the extremely luxuriantly growing American vines consume much greater amounts of water.

Tissue warts of this kind are much more abundant than is generally assumed and occur also on decorative plants[1]. They are reactions of the plant body to a wound stimulus or internal disturbances of equilibrium in the supply of water and nutritive substances.

Watersprouts.

By the term watersprouts, watershoots, or suckers, are understood exceedingly vigorous foliage shoots with long internodes, which grow up perpendicularly from old branches or trunks. Often trunks covered with *lichens* are distinguished by abundant sucker formation. Since the suckers grow up into the crown of the tree, they produce wood, and, indeed, unfruitful wood, at the very places which it is desirable to keep free from branches in order that sufficient light and air may reach the inner part of the crown. It is not advisable, however, to remove the suckers, if the cause of their formation is not removed at the same time. In many cases the cause may be found in an impervious subsoil. The roots of the vigorous tree reach this impenetrable layer sooner or later, which not infrequently is a vein of closely cemented sand containing iron. The absorption of food stuffs is limited by this, the tree forms only short shoots and smaller leaves, but still bears fruit. In a warm and damp spring, when all trees make a strong foliage growth, the energy of the weakened tree also appears to be increased by the favorable vegetative conditions. The strong upward force of the water causes the formation of adventitious buds or stimulates dormant buds, especially those not too far distant from the central trunk, since the upward force of the water and the nutrition is much more energetic in a perpendicular direction than in the more inclined position. Gardeners know how to turn this to use in growing plants on trellises. The horizontal branches on one side of the main trunk, which are weaker than the corresponding ones on the other side, are held in a perpendicular position for a year. This treatment results in a much greater and more rapid growth and development. With the production of water shoots a gradually increasing inequality in nutrition sets in, at the expense of the older, more horizontal branches which now suffer from scarcity of nourishment. This explains the death of the tip twigs of older lateral branches which begins with the appearance of the water shoots. One part of the tree starves when some other part develops very luxuriantly.

As has been said, it is scarcely advisable to remove the water sprouts during such a disturbance in the equilibrium of nutrition, rather, it is more advantageous in older trees to graft them with valuable varieties and, at the same time, to saw off a part of the older branches, so that the tree is thus rejuvenated. In places where the sub-soil cannot be opened up easily

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1 Sorauer, P., Über Rosenkrankheiten, Zeitschr. f. Pflanzenkrankh. 1898. p. 220.

the evil can be checked for a considerable number of years by using fertilizers at some distant from the trunk. The tree in its endeavors to reach the fertilizer develops a new vigorous root system. Young trees can be entirely cured by transplanting.

It must also be emphasized that the formation of suckers disappears of itself from many trees after a few years. This is the case where such water sprouts have been induced by an excessive pruning of the tree or the sudden dressing of the trunks. In avenues of trees, or along streets with telephone wires, and in tree plantations, through which a street or railroad line has been cut, a strong development of suckers is found on the sides of the trees toward the street.

Fig. 47. Fasciated branch of Picea excelsa.

The original band-like shoot (1), in one year, has developed three successive stages which sprout out from one another (2, 3, 4). (a) Bud scales (½ natural size After Nobbe.)

Fig. 48. Cross-section of the fasciated spruce branch.

A through the upper part of the branch, B through the lower part (a) bark with needle cushions (b) wood, (y) pith. (Natural size After Nobbe)

In such cases large branches are often simply chopped off on the side toward the street. Since the root system remains unimpaired, it pumps up just as much water as before the tree top had been reduced. By the removal of the branches, however, there is less consumption and consequently dormant buds are awakened which mature into slender shoots, becoming water sprouts whose buds often sprout even in the year of their production. Th. Hartig[1] has observed that these premature shoots develop no basal buds.

If suckers are produced by the sudden removal of large branches from the crown, their formation may be retarded by creating other diverting centers by scarification. In the spring pruning of branches, scarifying will, indeed, prevent the formation of the water shoots. In the same way, chopping into a vigorous root near the base of the trunk at the side where the tree crown has been greatly thinned out, will decrease the supply of water and prevent the sucker formation.

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[1] Vollständige Naturgeschichte d. forstl. Kulturpflanzen, p. 176

We may likewise consider as due to local over-nutrition the condition arising when a cylindrical branch becomes broad and flattened. It then looks as if a number of branches had grown together; nevertheless, this is only rarely the case, for almost always only a single branch is involved which, by broadening its vegetative point, no longer has a vegetative cone at its apex, but a comb-like vegetative surface[1].

In the illustration of a spruce fasciation here given (Fig. 47) we recognize the fact that the broadened axis is a single unit, first by the continued

Fig. 49. Fasciation of Alnus glutinosa.
(⅓ natural size After Noble)

spiral position of the needles, especially at *1* and *2*, and further in the cross-sections *A* and *B* (Fig. 48), of which the pith and wood form a single connected, uniform surface, and do not show any possible coalescence of many single adjacent rings, as must be the case where fasciation is produced by the coalescence of many branches originally separated. This theory is not changed by a consideration of the fasciation of the alder (Fig. 49), in which, besides the unusually characteristic crook-like bending of the

[1] Über Pflanzen-Verbänderung. Referat in Bot. Zeit. 1867, p. 232.

branches, resulting from a one-sided increase of growth, we can also perceive the splitting of cylindrical branches from the band bodies which occurs more frequently in deciduous trees. Thus the material for many axes, which can be isolated, lies accumulated in the fasciated stem, while the stem itself is a unit.

We can speak only hypothetically as to the production of the fasciations, which are characterized as hypertrophies by the great increase of the leaves and cords of the leaf spurs. An axis, which fasciates *later,* must originally have suffered some arrestment. We have seen already in roots held fast between split rocks that pressure from two opposite sides may give the axis a band-like form. Under certain circumstances such a changed direction of growth may continue if the cause of arrestment itself has disappeared. Thus Treviranus cites an observation on the stem of *Tecoma radicans* which had become band-like from pressure against the wall, but still remained band-like, after it had grown far out over the wall. Here the branches, which developed further, also became band-like in places.

Besides such lateral pressure, in other cases a transitory pressure from above may also probably cause a broadening of the vegetative point into a vegetative surface, and such pressure can possibly be produced by the abnormal behavior of the bud scales (delayed loosening due to resinification, drying, etc.). In case no abnormal increase of pressure occurs, direct injuries to the vegetive tip may cause the increase of the vegetable points.

If the fasciation has once been produced, it can be propagated by cuttings; even under certain circumstances it can be proved constant in the seed, as is seen in the favorite garden plant, cock's comb (*Celosia cristata*). The capacity for fasciation may be presupposed in all plants and actually observed cases have been reported in great numbers (150) by Masters[1]. As mentioned already, the fasciated growth produced by a band-like fastening together of isolated axes, should be distinguished from real fasciation. Lopriore[2] has produced such cases artificially in roots.

Compulsory Twisting (Spiralismus Mor.).

A. Braun[3] characterizes by the above name, those malformations of the stem which consist of barrel-like distended places in which the grooves, extending down from the leaves and representing the vascular bundles belonging to them, exhibit an extreme, spiral twisting. At times the barrel-like swelling is so great that the stem splits in the direction of the spiral twisting and divides into a number of spiral bands at these diseased places. Schimper has named this disturbance in growth "*Strophomania.*" The majority of cases are known in the families of the Dipsaceae, Compositae and the Rubiaceae. Single examples are described also for the Labiates,

[1] Masters. Vegetable Teratology, 1869, p. 20. (Compare Penzig and the isolated cases in the Bot. Jahresberichten.)

[2] Lopriore. G., Die Anatomie bandartiger Wurzeln. Cit. Zeitschr. f. Pflanzenkrankheiten, 1904, p. 226.

[3] Sitzungsberichte naturf. Freunde z. Berlin. Cit. Bot. Zeit. 1873, p. 11 and 20.

Scrophulariaceae, Cruciferae and, among monocotyledons, Asparagus, Lilium, Orchis, Triticum, etc., and also in Equisetum.

We think it justifiable to consider the compulsory torsion as a fasciation which has swollen up like a barrel. The cases have no agricultural significance.

Differing from them is the increased spiral twisting of normally constructed woody trunks, which we trace to an arrestment of the growth in length (usually resulting from a lack of water and nourishment).

Dropsy (Oedema).

a). In Small Fruits.

Since the propagation of standard gooseberries and currants by budding on vigorous shoots of *Ribes aureum* has found wider distribution, there has been a great increase in the complaints of a disease of the stock which makes doubtful the success of the budding.

This disease has been called "dropsy" by growers and consists in the appearance of closed bark tumors, i. e. of bark swellings entirely covered by the outermost cork layers, or of swellings rupturing later (Fig. 50 *A*). These swellings of the bark are sometimes small, but they may reach an extent of several centimeters. They are formed either on one side of the trunk or surrounding it, spreading into one another. They appear most abundantly on wood two or more years old, yet they can also occur in great numbers on branches one year old and directly cause their death, while the wood of the older branches may become diseased, to be sure, but does not directly die.

When, as is the custom at present, Ribes is grafted indoors in the spring, rupturing tumors are found frequently directly below the place of budding. In such cases the bud does not grow. But in extreme cases the same kind of swellings may also be found further back from this place, on the trunk between every two buds, as well as near the buds or, rather, the branches already developed from them. Cases are observed in which the base of a shoot left standing on wood one or two years old, has swollen up like a barrel and is covered by loose, hanging strips of bark. The branch above this place is dead.

As soon as the bark layer, which forms the outer skin of the branch and covers this fresh swelling, has split, the swollen place, pushing out from under it, exhibits a yellowish, spongy, soft, callus-like tissue-mass consisting of cells, elongated to pouches, very poor in contents but rich in water. (Fig. 50 *B s*). This is the former normal bark of which the cells beginning in the region between every two groups of bast cells (Fig. 50 *B b*) have elongated extraordinarily in the direction of the trunk's radius at the expense of their contents, otherwise rich in green coloring matter. They have partially separated from one another, and, by their constantly increasing extent, have finally ruptured the outermost oldest bark layers

(Fig. 50 *B e k*) which no longer participate in the changes and are separated prematurely by the cork layers (*k*) from the tissue lying beneath them[1].

The full thickness of the bark is not always attacked by the pouch-like elongation; in very severe cases, however, even the cells of the cambial region are deformed (*c*). The wood is no longer normal. Instead of normal mature wood, consisting of thick-walled, elongated wood cells and ducts,

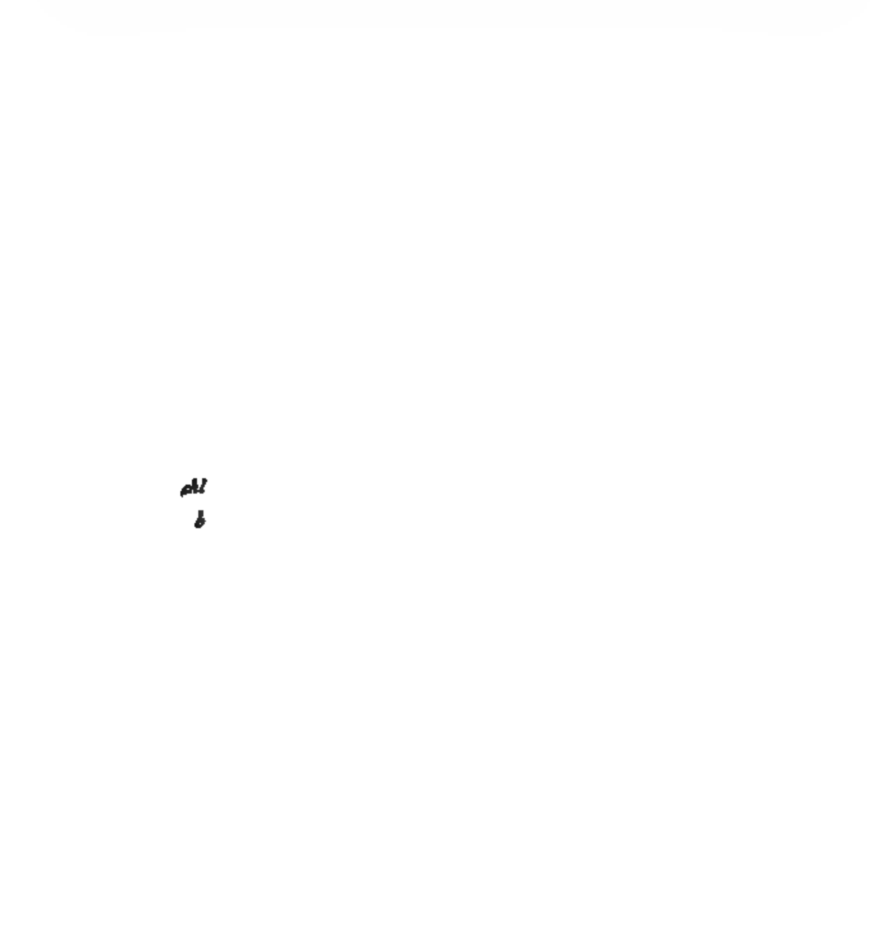

Fig. 50. Dropsy in **Ribes aureum.** (Orig.)

with cross walls broken through like ladders, a wood is produced, composed of short, broad, comparatively thin-walled, parenchymatous cells (*h p*). The cross-section (Fig. 50 *B*) shows the transition of the healthy side of the branch (*N*) into the dropsical side (*W*); *h* indicates the normal wood. At the time when the layer *st* was produced, the disease manifested itself in the

[1] Compare Sorauer in "Freihoff's Deutsche Gärtnerzeitung" August 1, 1880, and Göschke in Monatsschrift d. Ver. z. Beförd. d. Gartenb. October, 1880, p. 451.

cambium and the result was that, from there down on the diseased side, parenchyma wood (*h p*) was formed which at the left ended in a medullary ray (*m*). Still further towards the left, normal wood was produced at the same time. The same difference is found in the youngest bark parenchyma (*r p*). Because of the great radial elongation of the cells on the dropsical side (*W*) the hard bast cords (*b*) are pressed out like bows and the cell rows, containing calcium oxalate (*o*), which accompany the bast body, have also been correspondingly misplaced into steeply ascending, irregular rows. At *chl* are groups of parenchyma which have remained rich in chlorophyll. It is evident that this loose structure of the tissue, rich in water, which forms the swelling, has no great permanency. In dry places and with increasing dryness in the air, this tissue turns brown rapidly, shrivels, collapses and forms a soft, brown mass, part of which remains clinging to the wood, while part sticks to the outer bark tatters which roll back in times of drought and spread out, gaping, from one another. Such stems of such plants then have a rusty appearance and are best excluded from cultivation. Because of the ease with which such stock can be grown on strong soils, the loss from the disease would be less important, if it did not attack directly the potted specimens which have been budded and if the number of budded plants was not considerably decreased thereby.

I am not of the opinion, often expressed in general practice, that an over-abundant feeding of the plant is to blame, but I think that an excess of water makes itself felt in some places on the axis. If there should be an accumulation of plastic food material here at the same time, it would manifest itself preferably by an abundant cell increase. But this is not the case. If the cells on the healthy and on the diseased sides are counted, only an insignificant preponderance is found on the side attacked. Accordingly, an abnormal cell elongation is chiefly concerned here.

This is explained by the treatment of the Ribes stems during the preparation for budding. In order to obtain slender stems, growing tall rapidly, the other sprouts, produced at the sides, must be removed and even the lateral branches on the young stock must be cut back.

If now the stock is well rooted, it will grow rapidly in the greenhouse and the buds, scantily present because of the earlier pruning, are still further decreased by the fact that the shoots developing from them are cut back or entirely removed. By cutting off the branches, the amount of water forced up by the water pressure is increased in the main axis and manifests itself in a pouch-like elongation of the younger bark cells and in the formation of tumor swellings which finally rupture.

My attempts to produce dropsy by abundant watering and the rapid forcing of well-rooted specimens in the greenhouse, together with a continued removal of the developing lateral shoots, gave very favorable results.

The disease will be prevented if the budded stock is not forced too rapidly and the sprouts from the bud are cutting back carefully, but not

entirely removed. Maurer[1] has recommended the use of *Ribes nigrum* instead of *R. aureum* for budding stock. However, I have also known of cases of excrescences on the axes of the black currant, especially after the transplanting of such plants as tend to sterility.

b). In Stone Fruits.

It may be foreseen that, with the present methods of culture, phenomena similar to those observed with Ribes, will also appear in other varieties, for our fruit trees are becoming more and more delicate, due to the great increase in nutrition supplied them. The mass of the parenchymatous branch substance increases constantly in comparison with the prosenchymatous tissues. Between unbudded, wild stock, and budded varieties there are considerable differences. Direct measurements have shown me that the branches of the cultivated varieties acquire a fleshier bark while the wood ring decreases considerably in thickness[2]. I have called this increasing tendency of our fruit trees to form soft, parenchymatous tissues, storing up reserve substances, at the expense of the breadth of the wood ring, "*parenchymatosis.*"

In special cases this change in development acquires such extreme preponderance that diseases arise. I observed such diseases especially in the fruit wood of pears which is often shortened up to barrel-like fleshy swellings; growers call these "*Fruchtkuchen.*" The morbid disturbance consists either in the shedding of the cork layers and outermost bark layers in shield-shaped pieces from the side of the branch, thus showing a greenish yellow callus-like tissue mass, or in the uplifting of the bark itself in stiff. crumbly scales, like rings extending almost around the whole branch, with similar changes in the tissues. In the latter case, all the branches found above such a place are dead.

If the diseased condition manifests itself in a less luxuriantly developed fruit wood, which may be distinguished from the "*Fruchtkuchen,*" as *fruit spears,* a complete casting of these twigs was often found resembling that of the normal dropping of the twigs observable every year in poplars. In the present abnormal dropping in pears, the exposed surface was not smooth but uneven and woolly, light colored, however, like the cross-section of healthy wood.

A cross-section through a place in the branch which is found in the first stages of the disease, shows that the bark has developed strongly on one side, especially within the primary bark. Its parenchyma is thin-walled, vesiculated in places or pouch-like and extremely porous.

A comparison of the pith in a branch which has split and in a healthy one of equal age shows that the former is one-third larger than the latter, while the wood ring is only one-third as wide. Significant structural differences are connected with these misproportions. While a healthy shoot shows

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[1] Der Obstgarten, 1879, p. 182.

[2] Sorauer, P. Nachweis der Verweichlichung unserer Obstbäume durch die Kultur. Zeitschr. f. Pflanzenkrankh. 1892, p. 66.

normal libriform fibres and an abundantly developed vascular system, the wood of the diseased branch is made up almost exclusively of parenchymatous thin cells, between which the vascular cords are deposited. In normal trees, under certain circumstances, the weakness of the wood ring can be compensated for by schlerenchymatous elements in the bark[1].

The dropsical branches of pears differ from those of Ribes in that the wood body is also involved in the parenchymatosis and entirely broken up. By the rounding up and dilation of the wood cells, which have become parenchymatous, the ducts are gradually curved, displaced and finally torn. Just as soon as the loosening process has affected the whole extent of a fruit spear, or a "Fruchtuchen," dropping follows.

The diseased branches came from trellised trees in a well watered garden, richly fertilized with cow-manure.

Even if such extreme cases are less frequent, yet the first stages, consisting of the widening and excrescence of the medullary rays and the processes of elongation in various groups of bark cells, are often observed.

Swellings on the St. John's Bread Tree.

Swellings often appear as a result of cell elongation and cell increase. Savastano[2] reports thus, for example, of the outgrowths on the branches of *Ceratonia Siliqua.* Conical outgrowths, rich in tannin, are found at the tips of the flower stalks, causing atrophy of the blossoms. In an earlier study[3], he describes the production of *larger swellings on the St. John's Bread tree.* On normally developed fruit branches, in the beginning of the disease, the fruit falls in the first stages of development and the remaining basal part of the axial cone begins to swell. The repetition of this process in succeeding years produces a knotty swelling which can attain a very considerable size and a height of 6 to 10 cm. The bark of this hypertrophied tip of the fruit twig is often seven times as thick as that on the normal fruiting wood and the wood itself consists of ductless wood parenchyma. In the almost pithy bark, the bast fibres have wider lumina and take an unusual course. The medullary rays are twisted, the wood ring is often bent. In the parenchyma, various cell groups with discolored walls and a gummy content are recognizable. From the beginning of the disease, the tannin content of the swelling increases, causing a distinct disturbance in lignification.

A case described by Vöchting[4] in Kohlrabi plants may be mentioned here. If all the vegetative points were removed, the leaf cushions swelled to extensive structures. In the normal wood of the axis, as in the leaf cushions, the cambium developed thin-walled xylem elements. In similar

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1 Pieters, A., The influence of fruit-bearing on the development of mechanical tissues in some fruit trees. Ann. of Bot. Vol. 10. London, 1896. P. 511.

2 Savastano, L., Tumori nei coni gemmarii del carubo. Boll. d. Società d. Naturalisti in Napoli. 1888. Vol. II, p. 247.

3 Savastano, L., Hypertrophie des cônes à bourgeons (maladie de la loupe) du Caroubier. Compt. rend. 12. Janv. 1885.

4 Vöchting, H., Zur experimentellen Anatomie, cit. Bot. Jahresb. 1902. II, p. 300.

experiments with *Helianthus annuus* Vöchting found little tubercles formed on the roots. I observed barrel-like thickenings of the sharply bent roots of sweet cherries.

The swellings, described by Warburg[1] in the branch canker of the kina tree on damp soils, may also represent such correlation phenomena.

Retrogressive Metamorphosis (Phyllody).

If the organs of a morphologically higher developmental stage seem transformed into those of a lower one, we speak of a retrogressive metamorphosis. The change in the blossoming organs is pathologically of moment only if the sexual apparatus, by changing into a group of vegetative organs, loses the purpose for which it was designed and thereby initiates sterility.

These cases are listed under the group of phenomena caused by excess of water and nutriment, in accordance with the following theory. The development of the vegetable organism depends upon two factors, the constitution of the organic building materials and the way in which they are utilized. With the assumption that the first achievement of the organism,—assimilation, i. e., the formation of new dry substance,—takes place in a normal way, the development of the plant depends upon the way in which this organic building material is utilized. In this we recognize two directions which we will keep separate as the vegetative and the sexual generations. The latter is initiated usually by the appearance in the organism of an often clearly recognizable dormant period in the production of its vegetative apparatus. As a rule, new leaves are not formed at this time, the apical growth of the twigs stops. In place of this the process of the storage of reserve building material becomes conspicuous.

We find this storage process initiated and favored by a decrease in the absorption of water with increasing light and heat. An increased concentration of the cell sap is required, if the reserve substances, for example, are deposited in the form of starch. If such a concentration cannot be obtained under any circumstances whatever and the building substances remain in a diluted form,—for example, sugar,—only a slight impetus is necessary to start up vegetative activity. Thus, a certain antagonism prevails between the two developmental phases, which we may consider as transmissable adaptations to atmospheric conditions. After a cool wet period when the plant takes mineral substances from the soil and through the production of the leaves causes the chlorophyll apparatus to attain to its richest possible development, a warmer, drier period follows which makes possible the greatest amount of light. In this period the sexual organs are formed from the finished, plastic building materials prepared in the leaves and develop further, after a shorter or longer dormant period.

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1 Warburg, O., Beitrag zur Kenntnis des Krebses der Kinabäume auf Java. Cit. Bot. Centralbl. 1888. Vol. XXXVI, p. 145.

The more the plastic material is worked up by the leaves, the more numerous and perfect are the sexual organs formed within this dormant period. The manner in which these primordial buds subsequently develop depends on the nature of their further nourishment. If influences make themselves felt which are necessary for the maturing of the vegetative organs, foliage leaves will develop and, indeed, either from the newly formed centres or from the already existing primordia of the sexual generation. Thus "phyllody" takes place.

From our experience in horticulture, we know that an abundant supply of nutritive substances with a simultaneous increase in warmth and moisture, usually at the time of a lesser light action, are conditions initiating and favoring the process of phyllody. This becomes especially apparent in the production of double flowers, in which the stamens are transformed into petals.

Since this process can become hereditary, like all changes in the direction of growth, where conditions remain equal, and may be *increased,* it is evident that we will find examples in which the tendency to the retrogression of the sexual organs into forms of morphologically lower development, has affected all parts of a flower, and then the whole blossom *turns green.*

Of course, the influence of the soil is rarely the direct cause of phyllody. This is due rather to definite combinations of all the factors of growth, as already mentioned, and also occurs not infrequently as a correlation phenomenon resulting from the suppression of other processes of growth. Thus phyllody of individual flowers and inflorescences is produced by injuries to the vegetative axis and by vegetable and animal attacks (mites). For example, C. Kraus[1] removed leaves from *Helianthus annuus* plants of different ages, leaving only the bracts of the blossom head. In the older plants the bracts curled back and enlarged prematurely. In the younger plants 25 per cent. showed an actual phyllody, since the bracts assumed, more or less, the form of foliage leaves.

In my freezing experiments, I have often observed that the bud scales were transformed into herbaceous, leaf-like organs after the apical portion had been destroyed by frost. Goebel[2] obtained similar results by removing the leaves of young plants of *Prunus Padus,* Aesculus, Rosa, Syringa and Quercus, and then putting the plants into plaster casts.

Teratology has classified the phenomena. The simplest case is *"virescence,"* turning green, in which an organ of the flower retains its form in all essentials, but becomes green in color. As a rule, the organ becomes fleshier with this appearance of the chlorophyll coloring matter. In the actual metamorphosis of the floral organs into leaves (*phyllody, phyl-*

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1 Kraus, C., Untersuchungen über künstliche Herbeiführung der Verlaubung usw. durch abnorme Drucksteigerung. Forsch. auf. d. Geb. d. Agrikulturphysik. 1880, p. 32.

2 Goebel, Beiträge zur Morphologie und Physiologie des Blattes. Bot. Zeit. 1880, p. 803.

lomorphosis) the organ also approaches the foliage leaf in form. Bracts become normal stem leaves, the sepals are replaced by actual foliage leaves, the petals become green and fleshy, the pistils become stamens (*staminody*) or the stamens and pistils assume the character of petals or green, fleshy leaf-like structures, as, for example, in the double cherry, the double Ranunculus, etc. In mignonette, through phyllody of the ovules, little leafy axes can be formed in the urn-like open ovule cases. In the favorite tuberous Begonias, I found that the placentae had grown out of the ovule cases and the ovules carried over on to petal-like transformed branches of the pistil, etc.

There are cases in which all the parts of a flower are transformed into small, uniformly green leaves, i. e., a complete *green flower condition* (*chloranthy*) arises. One of the best examples of this is the green rose (*Rosa chinensis,* Jaqu.), received in its time with great enthusiasm, the transformation processes in which have been thoroughly described by Čelakowský[1].

I would like to introduce here also *parthenogensis,* which various scientists have often proved recently to be of constant occurrence. Kirchner[2] saw in this an arrangement "which, differing from the much more widespread, spontaneous self-pollination, serves to assure the development of seed, capable of germination, in cases where, for any reason whatever pollination has become uncertain or difficult." Even those seed primordia can be assumed to be of a somatic character, in which, at the time of the production of the embryo sacs, the reducing division is suppressed and the egg cell retains a vegetative character.

In cryptogamic plants *Apogamy* corresponds to the process of phyllody in the phanerogams. Instead of the sexual products, vegetative organs appear here, as in *Athyrium Filix femina* var. *cristatum, Aspidium falcatum* and *Pteris cretica.* It is said that in the last plant, no more female sexual organs are formed at all, but the young plant is produced from a vegetative sprout exactly on the places in the prothallium, where the archegonia must have stood[3].

Such plants which *"produce their young alive"* (viviparous) furnish abundant material for propagation, just as, for example, the bulblets of many lilies, produced by the transformation of a flower.

The Barrenness of the Hop.

A special process of phyllody, of great agricultural significance, is *the barrenness, the blindness, the fool's head formation* of the hop. The names designate only different degrees of a malformation which begins with a simple, abnormal lengthening of the catkins and develops into the formation

[1] Čelakowský, Beiträge zur morphologischen Deutung des Staubgefäfses. Pringsheims Jahrb. 1878, p. 124.
[2] Kirchner, O., Parthenogenesis bei Blütenpflanzen. Ber. d. Deutsch. Bot. Ges. 1904, Vol. XXII. Generalversammlungsheft. Here also a bibliography.
[3] Noll in Straszburger's Lehrbuch der Bot. 1894, p. 243.

of fluttering, dark green inflorescences on which develop foliage leaves, differing in size and varying in numbers.

Fig. 51. Different transitional stages between the normal hop catkin and a leafy one. (Orig.)

Hop growers know that the quality of the hop decreases according to the increased length of the catkin and enlargment of the bracts. The development of the catkins, most advantageous for technical use, is a short,

compact form of the whole inflorescence and a short, broad form and papery, thin consistency of the bracts, as shown in the preceding Fig. 51, Nos. *1* and *2*. Half of the leaves have been removed in No. *2*, in order to show the shortness of the joints in the catkin spindle. Nos. *3* and *4* show the abnormal excessive lengthening of the catkin, known among growers by the name *"brausche" hops,* which must count as the first stage of phyllody. Such "brausche" hops are coarse, contain less substance, ripen somewhat later and have more herbaceous bracts. Beginning with this condition, the phenomena of phyllody increase up to the stage shown in No. *5*. The green foliaceous leaves, which here become visible, attain at times the size of a normal leaf. *b* is the leaf blade which may be followed back into the petiole. At the base of this petiole stand the two green lateral leaflets (*n,n*) which in the present basal part of the catkin are very small, but increase in size upward. No. *6* is taken higher up on the inflorescence and shows the lateral leaflets (*n,n*) in a size equal to the other bracts, while the leaf body (*b*) is much smaller. The remaining bracts and protective leaves are seen at No. *5*. Each one encloses a flower.

The scale leaves, which exceed developmentally the other leaves and are developed only in the normal female inflorescence of the hop have the same bract-like constitution as do the protective leaves, so that the whole catkin seems composed of uniformly developed bracts. All the bracts are short lived and soon become dry skinned, when they lie over one another like tiles.

The barrenness consists, therefore, of the development of the otherwise suppressed leaf blade between every two bract-like leaves. Wide experience now shows that damp years[1] and soils strongly manured with substances containing nitrogen cause the more extensive appearance of the barrenness. Frequent summer rains, resulting in cloudy days, are often injurious, even without directly producing the disease. The cells of the leaf, as well as the axis, then elongate and even if favorable harvest weather occurs, the catkins ripen only superficially. They are brought into the storage rooms while containing much more water of vegetation, thereby causing a very *rapid heating* of the whole heap. Consequently, even in well-developed catkins, a rapid loss of the peculiar gloss and the light green color takes place, together with a considerable reduction in value of the whole harvest product.

As a remedy for the barrenness, the removal or checking of the causes must be attempted, in case these are found in the soil in the form of excess of water or nitrogen. If the cause is cloudy, damp air, all means should be utilized which further the greatest possible aëration and illumination of the hop-plantation. If nitrogen is present in the soil in excess, a subsequent fertilization with superphosphate is advisable.

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1 Beobachtungen über die Kultur der Hopfenpflanze. Published by the Deutscher Hopfenbauverein, Jahrg. 1879-82.

FORKED GROWTH OF VINES.

It may be noticed in various localities, that different varieties of vines assume a tendency to excessive branching and retain it hereditarily. The kind of false ramification appears as a forking of the vines and such diseased plants are usually little if at all productive. Rathay[1] published the most thorough observations on this subject and corroborated these statements in lower Austria. The wine growers there, who call these *branch-sick* vines *"Forks,"* or *"Double tipped,"* state that the forked formation may commence in very different places. The vines which in adjacent groups usually begin showing this abnormal direction of growth, first develop scattered forked branches and in this way present a "spurious forking" as may be seen everywhere in luxuriant vineyards. This initial stage of the disease is not dangerous, since the plants frequently return to a normal growth. The danger begins with the spread of the disease over the whole plant. Correlated with this is the transmissibility of the disease. This has been demonstrated in cuttings and suckers of affected vines.

No cause of this phenomenon can be given as yet with certainty. Rathay was convinced that parasites were not present. The opinions of practical workers disagree greatly. Some think that exhaustion of the soil by intensive grape culture is the cause, while others are of the opinion that a clogging of the soil due to heavy rain storms or to the working of the soil during and soon after rain has an injurious effect.

In my opinion this disease is a phenomenon of turning green—virescence—i. e., a morbid increase of the vegetative development.

Kaserer's[2] statements favor this hypothesis. He states that the first evidences of the disease are found in the transformation of the covering bract of the tendrils into a small leaf, the most advanced stage in the transformation of all the tendrils into leafy shoots. In grape vines, the tendrils are axial organs, of which the development depends upon the amount and constitution of the organic building materials present. In younger vines they become herbaceous shoots, but in older ones develop into inflorescences at the lower buds. If all the tendrils are transformed into leafy shoots the vegetative development will predominate, a morbid condition. The building material present is wrongly utilized. The cell sap necessary for the formation of the sexual organs is not properly concentrated. Thus far it is possible to agree with Krasser[3], who speaks of a diseased condition of the protoplasm in certain regions as a cause of this *"herbaceousness."*

If Krasser, referring to the works of Kober and Gaunersdorfer (1901) insists that no disturbances in conduction and no lack of nutritive substances can be assumed as causes of the "herbaceousness," which represents

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[1] Răthay, Emerich, Über die in Nieder-Österreich als "Gabler" oder "Zwiewipfler" bekannten Reben. Klosterneuburg, 1883.

[2] Kaserer, H., Über die sogenannte Gablerkrankheit des Weinstocks, Mitteil. d. k. k. chemisch-physiol. Versuchsstation Klosterneuburg, 1902. Part 6.

[3] Krasser, Fridolin, Über eine eigentümliche Erkrankung der Weinstöcke. II, Jahresb. d. Ver. d. Vertreter d. angewandten Botanik. 1905, p. 73.

only a metamorphosis of scattered buds into leaves, but that a very local affection of the cells of some buds is present, this does not upset at all our theory of phyllody. It is a matter of course that the formation of each organ takes place under definite nutritive conditions. That these change constantly and are the product of the *momentary* combination of all the factors of growth has been emphasized already in the introductory chapters of this edition. It is still far from possible to determine these combinations. For the present, we have only scattered observations on this subject,—that, for example, an excess of potassium and nitrogen in relation to the consumption of the other nutritive substances one-sidedly increases the vegetative activity at the expense of the sexual development. An excess of water with a relatively scanty supply of light can in a similar way influence the direction of growth. We cannot determine how these disturbances in equilibrium are produced individually for the formation of each organ, whether momentary arrestments in the absorption or transportation of the nutritive substances form the cause.

We can, therefore, state only very generally that phyllody is produced by a preponderance of the direction of growth producing green leaves as against the mode of growth favoring the sexual organs. The so-called "*changelings*" or spurious forkings, are plants which are still partially fruitful. Among the conditions favoring the tendency to phyllody, Kaserer cites unfavorable positions on which drainage water collects from higher lying ground. Healthy plants set out in a group of affected plants are said to fork rapidly. Superphosphate seems to favor a return to fruitfulness.

We consider the replacement of diseased plants by healthy ones of varieties which withstand a more abundant supply of water and heavier soils to be the most advisable mode of procedure. The so-called aggregations of forked plants might be improved by drainage and the addition of sand together with that of calcium phosphate.

Falling of the Leaves.

The falling of the leaves, the normal result of age[1], is of pathological significance only because, under certain circumstances, it can appear prematurely.

The causes which may lead to such premature dropping of organs are of different kinds, and extremes of weather may give rise to it. Accordingly, the phenomena could be treated in different sections of this book. Nevertheless, we prefer to consider here the processes of loosening as a whole, because they are connected with changes in the tissues, in which increases of turgor occur decisively, after the organs, for any cause whatever, have become *functionally weak*. In regard to the falling of the leaves, for example, Wiesner[2] differentiates the falling of the leaves into a *summer*

[1] Dingler, H., Versuche und Gedanken zum herbstlichen Laubfall. Ber. d. Deutschen Bot. Ges. Vol. XXIII (1905), p. 463.

[2] Wiesner, Jul., Ber. d. Deutschen Bot. Ges. Vol. XXII (1904), p. 64, 316, 501. Vol. XXIII, p. 49.

falling, falling due to growth, falling due to heat and falling due to frost. Pfeffer[1] gives us an insight into the diversity of the causes. "Such a hastening of the leaf-fall is brought about, for example, by insufficient illumination, also by an insufficient water provision and by too high a temperature. Not infrequently, however, a premature shedding of the leaves is caused especially by the *sudden change* of external conditions, which for pertinent reasons concern first of all the older leaves." As examples of the injurious influence of a sudden change in the amount of transpiration, Pfeffer cites the sudden loss of leaves in plants as soon as they are brought from the moist greenhouse air into a dry room. Sharp changes of temperature, illumination, etc., can act in the same way.

v. Mohl[2] has studied the anatomical processes very thoroughly.

The shedding of leaves is accomplished by the formation of a transverse parenchyma layer at the base of the petiole, as a rule within the leaf cushion, and, in fact, usually where the cork of the bark passes over into the epidermis of the petiole, and in the interior of the petiole tissue, which is produced by a special cell division. The cells of this layer separate from one another in one plane.

v. Mohl calls the zone in which the layer of separation is formed, the *"round-celled layer,"* because it consists of very short parenchymatous tissue, which toward the leaf body gradually passes over into the elongated cells of the petiole, but is sharply defined on the side toward the bark of the twig.

In very many cases, a cork layer formed of plate-like cork cells, separates the green bark of the branch, rich in chlorophyll and starch, from this short-celled parenchyma of the round-celled layer of the leaf cushion which usually contains no starch, and very little cholorophyll and turns brown at the base at the time of leaf fall. Schacht[3] considers this cork sheet, which, at the sides, passes over into the inner cork layers of the bark, to be the cause of the shedding of the leaves. In fact, it may be assumed that if a cork layer be shoved in between the tissue of the bark and that of the petioles, the food supply of the leaf is impoverished and the leaf gradually goes to pieces. Nevertheless, the cork layer is not the cause of the leaf fall, for v. Mohl has shown that it is not formed in many plants which cast their leaves. Thus, for example, no cork layer can be found in ferns with deciduous fronds (Polypodium, Davallia) further, in *Gingko biloba, Fagus silvatica,* some varieties of oak, *Ulmus campestris, Morus alba, Fraxinus excelsior, Syringa vulgaris, Atropa Belladonna, Liriodendron tulipifera,* etc. On the other hand, the cork layer is formed in *Populus canadensis* and *P. dilatata, Alnus glutinosa, Juglans nigra, Daphne Mezereum, Sambucus racemosa, Viburnum Lantana, Lonicera alpigena, Vitis vinifera, Ampelopsis quinquefolia, Aesculus macrostachya, Pavia rubra* and *P. lutea, Acer*

1 Pfeffer, Pflanzenphysiologie. II Edition, Vol. 2 (1904), p. 278.

2 v. Mohl, Über die anatomischen Veränderungen des Blattgelenkes, welche das Abfallen der Blätter herbeiführen. Bot. Zeit. 1860, Nos. 1 and 2.

3 Schacht, Anatomie and Physiologie, II, 136.

platanoides, Prunus Padus, Robinia Pseudacacia. The cork layer should, therefore, be considered only as a protective layer for the bark tissue exposed by the falling of the leaf, often developed before the leaf has fallen.

The real layer of separation, in fact, is formed above the cork layer in the almost isodiametric parenchyma of the round-celled layer, not in the brown-walled portion bordering directly on the cork, but in the adjacent healthy portion, of which the walls are light colored. There, shortly before the leaves fall, a zone is found running obliquely in front of the bud toward the outer side of the petiole and composed of young, delicate walled cells with intercellular spaces containing less air. Small starch grains are found in these cells which otherwise do not occur in the enlarged end of the petiole. In this newly formed tissue-zone, the cells separate from one another without tearing, but by rounding off, as Inmann[1] has observed. One part remains attached to the petiole as it breaks off, the other to the leaf scar where it soon dries up. The leaf-fall, accordingly, is a *vital* act, not a mechanical one. Before the leaf falls, vascular bundles take no part in the changes undergone by the cell tissue of the swollen end of the petiole. These extend through the round celled layer and the cork layer without changing their organization, even without turning brown. The cleavage in these takes place in a purely mechanical way after the split has extended through the parenchymatous tissue.

In many plants (Nuphar, many monocotyledons, herbaceous ferns[2]) in which there is no cork formation on the leaf scar, its outer dried cell layers pass over directly into the healthy bark parenchyma and are thrown off during later development.

v. Bretfeld[3] arrives at the conclusion that the process of abscission of the leaves is the same in monocotyledons and dicotyledons, only the shutting off of the abscission surface differs in different genera. An essential difference lies, however, in the time of the formation of the tissue zone in which the separating layer is produced. While in dicotyledons, the process of abscission is the product of living activity, taking place shortly before the leaves fall, this process in the tree-like monocotyledons, orchids and Aroideae is exhibited as an act *prepared* by the primordia of a definite layer and advancing with the general tissue differentiation.

The loss of leaves occurring in conservatory plants of the herbaceous and bushy Begonias, of Cistus species and many Mytaceae and Leguminoseae from New Holland must be mentioned in discussing leaf fall due to an excess of water. The upward force of the sap is increased excessively by an abundant watering of the plants at the time of minimal leaf activity. The cleavage surfaces of the falling leaves at times are very mealy, due to the loosened cells of the abscission surface.

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1 Bot. Zeit. 1850, p. 198.

2 v. Mohl, Über den Vernarbungsprozess bei der Pflanze. Bot. Zeit. 1849, p. 645. p. 645.

3 v. Bretfeld, Über den Ablösungsprozess saftiger Pflanzenorgane Bot. Zeit. 1860, p. 273.

Leaf Casting Diseases.

The *leaf casting diseases* form the most significant case of premature dropping of the leaves. We speak here in the plural, although it is customary generally to call a sudden dropping of the needles of young pines "leaf casting." All plants can "cast their leaves" which are capable in any way of pushing off their dying leaf apparatus. The only concern, then, is whether the leaf body in its entirety suddenly becomes functionally weakened, or even functionless. It is only because it appears so uncommonly abundantly among pines and is accompanied by severe results that the *dropping of the pine needles* is cited especially often for "Leaf Casting."

This form of disease manifests itself most frequently and severely in seedlings two to four years old, the needles of which suddenly become brownish-yellow or brownish-red in the spring and fall after a short time. The considerable spread of this phenomenon dates only from the general change in the cultural methods; instead of sowing the seed and of the Femel management, the raising of plants in seed beds has been introduced.

Since that time it has been observed that in the months from March to May, often within a few days, great areas of seedling plants look as if they had been burned. In this, however, it can be noticed that young plants protected by a not very close conifer forest, or one of mixed trees, or, in nurseries protected by trees of an earlier seeding, do not cast their needles, while exposed areas in the open or in enclosed places are extraordinarily attacked by the disease. Specimens with pruned roots suffer more than those with long, vigorous ones, while plants on wet soil suffer most intensely. Mountain plantations are less attacked than those on plains and a northern exposure seems to be almost entirely spared, while a southern or western one suffers greatly.

The disease does not appear every year, but generally only after wet, cold winters with but little snow, and alternating sharp frosts. The plants cast their needles most extensively if dry springs, March and April, are distinguished by bright warm days followed by cold nights. Often the phenomenon occurs in stripes or spots. It has been observed further, that plants protected from the noonday sun by neighboring woods, etc., generally did not become diseased. Plants in seed beds, which were left covered until after the time of spring frosts, did not cast their needles while adjacent, unprotected seedlings did so. Seedlings grown between older covered plants or between broom plants, even those protected by high grass, did not develop the disease, while others where the broom plants had been dug out in the spring were attacked.

Ebermayer[1], in explanation of these facts, states that observations of a forestry experimental station, made for several years, showed that in March and April the soil temperature down to 1¼ meters was scarcely more than

[1] Ebermayer, Die physikalischen Einwirkungen des Waldes auf Luft und Boden etc. Resultate der forstl. Versuchsstat. in Bayern. Aschaffenburg, 1873. Vol. I, p. 251.

5 degrees C., while the air temperature in the shade not infrequently was higher than 19 to 22 degrees C. Such differences in temperature between the air and the soil result directly in the excessive transpiration of the aërial parts of the plant, while the roots kept in a state of inactivity because of the cold soil, are incapable of taking up the soil water, or not to the amount necessary to replace the aërial loss. Thus the young pines dry up even when the soil is abundantly wet.

The greater the difference between the soil and the air temperatures in direct sunlight, the more abundant and devastating is the leaf casting. On the other hand, the more frequently conditions arise which raise the soil temperature, such as warm spring rains, or which prevent a greater lowering of it, i. e. masses of long unmelted snow or of mulch, the less the disease appears. This lessening of the disease will take place also if the temperature of the air and the intensity of the sunlight are decreased as, for example, by a very cloudy sky, by a position on northern slopes, or under the protection of larger trees, high grasses or bushes, or by the artificial screening of the seed beds during the day.

That older plants suffer less often from leaf casting is explained, in the first place, by the more strongly developed wood which in all plants may be considered as a water reservoir; in the second place, by a more abundantly developed, deeper reaching root system, which possesses more organs for absorption in its greater number of fibrous roots.

Holzner[1] has raised an objection to this theory. In leaf casting, discoloration appears within 2 to 3 days, while, in an actual process of drying, the pine needles redden only gradually. He considers the cause a direct effect of frost. It is a well established fact that frost will also cause leaf casting. Baudisch[2] protected seedlings by a brush covering one meter deep above the surface of the soil. The plants which had remained healthy until the protection had been removed then suffered from the April frosts.

Many authors ascribe an injurious influence to autumn frosts[3]. The theory most generally accepted at present considers the disease to be parasitic and, accordingly, recommends that it be treated with fungicides. According to v. Tubeuf's[4] experiments, it cannot be doubted that there are also cases of parasitic leaf casting[5]. However, the fact must be taken into consideration, that the fungi of leaf casting are present in abundance on older pines, firs, spruces and larches, without calling forth the specific phenomena. Therefore, unless some conditions especially favorable for the much dreaded juvenile disease are present, it cannot become epidemic.

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1 Holzner, Georg. Die Beobachtungen über die Schütte der Kiefer oder Föhre und die Winterfärbung immergrüner Gewächse. Freising, 1877. Here bibliography of 145 studies on leaf casting.

2 Centralbl. f. d. ges. Forstwesen VII, 1881, p. 362.

3 Alers in Centralbl. f. d. ges. Forstw. 1878, p. 132. Nördlinger ibid p. 389. Dammes and others, Jahrbuch d. schles. Forstvereins 1878, p. 40 ff.

4 v. Tubeuf, Studien über die Schüttekrankheit der Kiefer. Arb. d. Biolog. Abt. am Kais. Gesundheitsamt. Part II, 1901.

5 Cf. Vol. II, p. 268.

All these statements as to the factors causing leaf casting agree in maintaining that the needles fall because they have become weakened functionally or still are normally weak as a result of the winter's rest. Moreover, the abscission process depends upon the development of the cleavage layer which presupposes living activity and an increased turgor. Thus, there arises an antagonism; the leaf organ is not at the time in a condition to function as a normal center of attraction and consumption. Because of its anatomical structure the basal part above the region of the subsequent cleavage can be excited and it is prematurely brought to the development of this cleavage layer by the increase in turgor, which arises in the spring due to exposure to the sun, or has been retained from the previous year, and finds no equalizaion since even the inactive lamina of the leaf do not take up the water from it. *This disturbance in the equilibrium of the turgor distribution is the cause of all premature dropping of the leaves.*

In the special case of the pine leaf casting I think that the contrasts described by Ebermayer and, indeed, the sharp *contrasts,* represent the most frequent cause of the disease. Only in explaining it, I differ from him in so far that I accept as cause the winter's inactivity, evident also in the constitution of the chloroplasts, instead of the excessively increased evaporation from the needles. Only the base of the needle is excited and develops the cleavage layer, which, as will be mentioned under petals, can, under certain circumstances, be produced in an extremely short time. I am of the opinion that the needle does not become dried out, but is *put out of action* by the cleavage layer. I would like to assume from the absolute scanty elimination of water by pines in winter, that a drying of the needles resulting from an excessively increased evaporation, is not the cause of the discoloration and falling of the needles. An experiment in a water culture of one year old seedlings showed me that a pine ceased its evaporation on the 17th of November despite following days with temperatures of + 3, 4, 7, 9 degrees C. Up to the 22nd of December they did not evaporate one gram more of water, although the root stood in water[1]. It can, therefore, scarcely be assumed that the spring temperature can, in a few days, cause a great loss of moisture, more particularly as the pine is a tree species which evaporates the least of all[2].

Since the drying of the needles does not seem to me to be the cause of leaf casting, but rather a lack of equallization in the water supply, resulting from the sharp contrast between the needle surface, weakly assimilative, and its base, already active, I would like to believe the best preventative method to be the avoidance of such sharp contrasts: I, therefore, add the proposals made by Ebermayer:—

A. Increase in soil temperature: (1) due to the prevention of too great cooling during the winter by means of leaf, brush or moss coverings; (2)

[1] Sorauer, Studien über Verdunstung. Forschungen auf d. Gebiete der Agrikulturphysik, Vol. III, Parts 4 & 5, p. 10.
[2] v. Höhnel, loc. cit. Vol. II, p. 411.

by draining wet soils; (3) by loosening and mixing heavy soils with earths rich in humus, so that the warmth of the air can penetrate more easily.

B. Lessening of sharp contrasts by shading: (1) by brushing the seed beds with evergreen boughs, which should not be removed on warm days; (2) by making the seed beds in places which are protected on the south by tracts of trees.

"In the restoration of pine woods, on the whole, the most radical means consists in a return from the extensive clearing system to a plan of seeding, such that the young plants have the necessary protection from the *direct* sunlight in the overhead wood protection, but can still obtain as much light as is necessary for their vigorous development. The same end is attained by a slender fringe of trees running from N. E. to S. W., which are much used at present in the restoration of the pine tracts. In the cultivation of extensive clearings the shading can be obtained by a shelter growth of such plants as are favored by the habitat,—for example, by birches, etc., or by previous spruce plantations."

"In cases, where no shelter growth can be arranged because of local conditions, the planting of seedlings is preferable (yearling plants with a good root system seem best suited for this), yet the first two cultural methods will much more surely attain the desired goal."

Finally it is well to emphasize that every attention should be given to obtaining a good root system;—accordingly, too thick seeding, heavy, unbroken soil, considerable injury in transplanting and the like are to be avoided.

A leaf casting occurs also in older trees. The older needle bunches of plants standing on moor-soils in misty depressions, or found in localities subject to extreme frost, fall prematurely. But, in the autumn, these hang to the trees, turning yellow or drying up, and are thus distinguished from the seedlings specifically diseased with leaf casting. On heavy soils the pine always dies easily[1].

Leaf-Fall in House Plants.

Among the most delicate of the house plants belong the *azaleas*, because, as a rule, they suddenly drop their leaves in summer or in the autumn; the broom-like little tree then at best develops only a few pitiful flowers. Here too are concerned sharp contrasts occurring suddenly. Either the plants (usually set in moor soil) in summer are left too dry, and later watered very abundantly, or they are brought too suddenly into the warm house in the autumn. In both cases, the leaves are weak functionally and then their functioning is increasingly stimulated by the increased upward pressure of the water. If the transition is brought about gradually, the inactive leaf surfaces would have time to resume their normal action by a general slow increase in their turgidity and there would be no resultant injury.

[1] Runnebaum, A., Das Absterben und die Bewirtschaftung der Kiefer im Stangenholzalter usw. Zeitschr. f. Forst- u. Jagdwesen, 1892, p. 43.

But, with the sudden upward pressure of the water, the basal region alone is stimulated, thus causing the development of the cleavage layer.

In foliage Begonias, rubber plants, camelias and many others, the leaves begin to drop in the autumn and winter. Here, the leaf is in a natural, dormant state. Abundant watering in a warm room causes an upward current of water which the leaves cannot utilize.

Here are briefly a few of my own observations. A *Begonia fuchsioides* which had been forced through the winter in a warmer room, was brought at the end of March into an unheated, but sunny room. Within a few days it dropped all its leaves except the youngest ones. *Libonia floribunda,* which had been kept very cold, was suddenly brought into a greenhouse in December for forcing. The plants dropped all the older leaves, while plants remaining in the cold retained theirs. Some specimens of a double white fuchsia were brought into the house in the autumn in order to get early shoots for cuttings. Other specimens of the same variety were left in the cellar until the beginning of March. At this time the tips of all the plants were set as cuttings in a bench with 25 degrees C. soil heat. After a few days the cuttings, from the plants in the cellar, lost their leaves up to the very tips, while the others had not even lost the leaf at the cut surface. The tips of one branch, taken a few days later from a cellar plant, were placed in sand in the cellar, without any especial care and were found in May to have rooted, while the tips from the cellar plants had gone to pieces in the warm case.

For house plants it may be recommended as a fundamental principle that the plants should be subjected *gradually* to other vegetative conditions, and the *dormant period,* upon which every vegetative plant enters, should not be interrupted by an increase in the supply of heat and moisture.

The Dropping of the Flowering Organs.

This process takes place in the same way as that of the leaves[1]. The composite axes of the inflorescences in Aesculus and Pavia are known to separate into their individual parts, which loosen from one another with smooth cleavage surfaces. In the same way, if many fruits are set, a number of half-grown ones are often abscissed to a joint in the fruit stem. The staminate blossoms of the Cucurbitaceae are abscissed at the cleavage layer formed on the boundary between pedicel and blossom, those of *Ricinus communis* in a line of separation, produced at a joint lying in the lower part of the peduncle. The hermaphrodite blossoms of *Hemerocallis fulva* and *H. flava,* left unfertilized, are abscissed by a cleavage layer extending under the base of the blossom through the upper part of the peduncle. The cells of the cleavage surface round up and separate from one another.

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[1] v. Mohl, H., Über den Ablösungsprozess saftiger Pflanzenorgane Bot. Zeit. 1860, p. 273.

In the same way a fully developed cleavage layer is found in the sepals of *Papavcr somniferum, Liriodendron tulipifera,* at the time they fall; in the falling parts of the calyx of *Mirabilis Jalapa, Datura Stramonium;* in the petals of *Rosa canina,* Papaver; in the single corolla of *Lonicera Caprifolium, Rhododendron ponticum, Datura Stramonium;* in the stamens of *Lilium bulbiferum* and *L. Martagon, Dictamnus Fraxinella,* Liriodendron; in the stigma of *Lonicera Caprifolium, Mirabilis Jalapa* and *Lilium Martagon.*

In the majority of cases, the cells of the abscission layer contain no starch, or at least no more than does the surrounding tissue, while, in the leaves and thick sepals and petals of Liriodendron abundant starch is present. This lack of reserve nutriment is explained by the rapid formation of the cleavage layer in the blossoms, for which the momentarily transportable nutritive substance is sufficient. In the sepals of *Papaver somniferum* the cleavage layer is produced in a single night, in the petals of single roses, in the hours of an afternoon. While cell increase seems to occur in the cleavage layer of leaves, it can hardly take place in the petals. The processes there visible consist only of a more abundant protoplasm, an increased porosity and mutual separation, due to a rounding up of the cells, and, at times, a pouch-like enlargement of the cells, whereby the cleavage layer looks velvety. The appearance of the cleavage layer is delayed as the organs are better nourished.

The Shelling of the Grape Blossom.

By the term "shelling" or "falling" the winegrower means the dropping of blossoms soon after blooming. In some regions the phenomenon returns annually while, in other localities, it appears only in isolated years, as, for example, in those when wet, cold weather destroys the blossoms. According to Müller-Thurgau's[1] investigations, with a low temperature at the time of blossoming, the cells of the stigmas were beginning to turn brown even before the blossom sheaths fell, which indicated death or at least an extensive retarding of the process of pollination. Actually, on such stigmas the pollen grains did not develop pollen tubes at all, or only poorly. The dropping of the petal cap took place very slowly or was entirely suppressed. The ovule cases of such blossoms remained for some time, often actually for a long time, but they scarcely enlarged at all. However, since, according to Müller's discoveries, *ringing of the vines* is usually beneficial, the low temperature cannot be the direct cause of the incompleted act of pollination and the failure to mature the seed. The dull, cool weather during blossoming is especially favorable for the growth of leafy shoots, which, on this account, require the material stored up for the development of the inflorescence, so that the nutrition is not sufficient for the blossoms. *Such a starving of the blossom cluster* and, consequently, a more or less

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[1] Müller-Thurgau, Über das Abfallen der Rebenblüten und die Entstehung kernloser Traubenbeeren. Der Weinbau, 1883, No. 22.

extensive shelling of the blossoms will occur also with weather favorable for blooming, if abundant nitrogen is present in the soil, or if virgin soil with an abundant supply of nutrients and water is used for the cultivation of grapes, when the luxuriant development of the vegetative organs limits the further development of the sexual apparatus.

In fact, Müller gives examples of such cases and, at the same time, states his experience, viz., that sometimes fertilization has helped overcome the evil, and sometimes a long incision in the vine accomplishes the same end.

Müller also ascribes to the same causes the appearance of *seedless grapes* on the bunch, which, as a rule, is correlative with a partial shelling. The seedless grapes are larger than the unpollinated seeded ones which, at times, remain on the bunch even until autumn. The seedless ones, however, are not as large as normal, seed bearing grapes, although, like them, they color and become sweet. Indeed, it is evident that they ripen earlier and become sweeter than the grapes with matured seeds.

Since the seed primordia in the seedless grapes do not seem much larger than at the time of blossoming, it must be assumed that some disturbance had taken place at that time. It is probable that, in such cases, pollinization had taken place, but that either a temporary lack of suitable nutritive substances, or some other disturbance, prevented the further development of the egg cell. The stimulus, exercised by pollination on the walls of the ovule cases is present and the grape consequently develops. Since, however, it does not need to use up any of the nutritive substances flowing towards it in maturing the seeds, this grape at first exceeds developmentally the grapes containing seeds. Weighing seedless and seeded grapes proves that the seed, in maturing, functions as a centre of attraction for material. Müller-Thurgau[1] found that the weight of the fruit flesh of 100 berries of Riesling was

Seedless	With 1 Seed	With 2 Seeds	Normal, with 4 Seeds
25.0 g	58.2 g	77.2 g	112. g

As examples of the differences in the material development, the results of an experiment by Müller with Riesling may be cited here.

1000 berries on the 25th of September showed

Seedless	a weight of 208.9 g,	sugar 10.63%,	acid 18.2%
Containing seeds ...	a weight of 846.0 g,	sugar 9.77%,	acid 24.2%

On the 12th of October

Seedless	a weight of 231.0 g,	sugar 14.7%,	acid 11.0%
Containing seeds	a weight of 898.7 g,	sugar 12.3%,	acid 15.7%

In regard to the effect of ringing, an experiment showed that the nonringed vines bore only unfertilized grapes, which fell soon, while the bear-

[1] Müller-Thurgau, Einfluss der Kerne auf die Ausbilding des Fruchtfleisches bei Traubenbeeren und Kernobst. II. Jahresbericht d. Versuchsstat. Wädensweil. Zürich, 1893, p. 52.

ing vines, which were ringed shortly before blossoming, furnished comparatively long bunches with an extremely large number of seedless berries, between which were found only scattered normal ones.

This formation of seedless grapes is a great injury, under our present conditions, since the prematurely ripe grapes shrivel before the general vintage until all the juice is lost, and drop off or decay; they, therefore, are wasted. If, on the other hand, this degeneration is increased, it may be termed an advantage. Probably our currants and Sultana raisins, among which only scattered berries with seeds are found, are the products of plants in which a seedless condition of the berries has become the rule. In other localities, cuttings of the currant grape are said to bear grapes with seeds.

Eger[1] gives some advice well worth considering. He studied the individuality of different varieties of grapes from many points of view and found that certain plants of the same variety always ripen their berries earlier and that many, under otherwise similar conditions, show a lesser tendency to the falling of the bloom, which, especially in Riesling, is very considerable. Accordingly, in each nursery and vineyard those individuals should be labelled which are notable each year because of their favorable development, and *only* from these should cuttings be chosen for propagation.

Other processes are found in our stone fruit trees when grown for trade. If the *wood is thinned too much*, i.e. too many leaf branches are cut away, in order to furnish light for the blossoms and young fruit, the buds, blossoms and young fruit may be dropped. By the sudden decrease of the evaporating leaf surfaces, an increased root pressure sets in for the other organs, which cannot take up the increased amount of water. Cleavage of the abscission layer results. The dropping of the organs can naturally be initiated by other causes[2].

THE SHEDDING OF THE YOUNG FLOWER CLUSTERS OF HYACINTHS.

Many shipments of hyacinth bulbs from different growers have shown me that the shedding of complete but undeveloped flower clusters is not of rare occurrence. The uncolored, otherwise perfectly healthy flower clusters, still rather short, may be lifted from entirely healthy bulbs with fully developed, often excessively elongated foliage. In the very luxuriant variety Baron Van Thuyll (originated in Holland) I found yellowish areas on otherwise normally developed leaves and these areas were slightly swollen, even split here and there. The flower clusters were strong, perfectly healthy, perhaps 8 cm. in length, with an equally long, perfectly healthy, almost colorless stalk.

The stalk had separated from the base of the bulb and the cells of the former were found to be swelled up more or less ascus-like. This swelling

[1] Eger, E., Untersuchungen über die Methoden der Schädlingsbekämpfung und über neue Vorschläge zu Kulturmafsregeln für den Weinbau, Berlin, P. Parey, 1905, p. 63.

[2] The Dropping of the Buds of Peaches. Gard. Chron. XIII, 1893, p. 574.

could be traced back from the place of cleavage, to varying depths. The pro-cambial cells of the firo-vascular bundles were broadened like bladders.

The ducts thus exposed were simply broken off and, like the other exposed surfaces, had absolutely uncolored walls at first.

The separation begins to show itself in the rounding up and bending outward of scattered cells in the basal tissue of the flower stalk, usually at a short distance from the base of the bulb. Simultaneous with the beginning of this convexity a swelling of the membranes of these cells appears at the side where the curvature sets in. It is the striated middle lamella of the cell walls which swells. Also, the swelling does not take place uniformly in the whole membranous layer, but in some places to a greater degree than in others, hence the swollen, stripe-like areas have a knotted course, in places showing constrictions.

A *bead-like* irregular condition of the outer surface of the cell walls in the cells lying next the cleavage surface seems worthy of attention. The hemispherical, to nipple-shaped swellings correspond to those in the woolly stripes in the apple core and take on a pure golden yellow color with chloriodid of zinc while the rest of the membrane becomes intensely blue. This disturbance sets in if, when growth starts, the hyacinths bulbs are given at first too great warmth and too copious watering. The flower cluster, not yet beginning to elongate, cannot utilize or absorb the water brought to it by the increased root pressure. Thus an excess of water is accumulated at the base of the flower stalk, whose cells elongate and weaken their connection.

A *slower forcing* of the hyacinth might prevent this condition.

Twig Abscission.

The small branches which, usually, together with their fully developed foliage, are cut off from the main axis by some organic process may be called abscissed twigs. This abscission takes place chiefly in the autumn, yet it has been observed in summer (July) and as in leaf casting we must take into consideration different causes for the same phenomenon. All trees do not show this peculiarity and even those in which it appears do not shed their branches every year[1], nor do all of them do so. Young, vigorous trees often do not shed, while older specimens, or those standing on poor soil, in the autumn cover the ground underneath them with branches.

The poplars[2] furnish the best known example. Their branches, often meters long, with their swollen, hemispherically rounded joint-like abscission surfaces, smooth and shining like velvet in damp weather, show most clearly that the branch is not loosened by a forcible tearing of its component parts, but by a separation of certain tissue zones preceded by internal organic processes.

[1] Borkhausen, Forstbotanik I, p. 294.

[2] K. Müller, Hal., Der Pflanzenstaat, p. 532, gives an illustration of this.

The abscissed branches of oaks[1] should be mentioned. In spruces except. for the twigs frequently found bitten off by squirrels[2], there are probably no actual abscissed twigs.

Further, this phyllocladia, or loosening of the branches, has been observed in Xylophylla and Phyllocladus[3], in all Dammara species and especially in *Dammara australis,* according to A. Braun, in several Podocarpus species, in Guajaceae, Piperaceae, many bushy Acanthaceae, in *Laurus Camphora, Crassula arborescens, Portulacaria afra, Taxodium distichum*[4], in Tilia[5] in *Ulmus pendula,* Evonymus, *Prunus Padus,* Erica, Salix[4], etc.

The trees partially owe their characteristic habit of growth to these abscissed twigs. But the process of freeing varies according to the habitat, weather and other agencies. Thus Röse, for example, emphasizes that, with continued drought, the branches fall more abundantly; in the majority of cases, side shoots are dropped, but many plants lose their tips as well. The last case is observed most frequently in young trees grown on fertile soil. Nördlinger[6] emphasizes that predominantly the weakly grown branches are the ones shed.

Just as we find the leaves falling in summer, we also find a summer abscission of the branches. Gymnocladus, *Catalpa bignonioides,* Gleditschia, Tilia and especially *Ailanthus glandulosa* exhibit the same formation of an abscission layer and the separation of the cells from one another as found in the case of fallen leaves. In young shoots of Ailanthus it may be observed that, besides the parenchyma, even the still unlignified cells of the vascular bundles are involved in the formation of the cleavage layer. No cork is developed at this time either near the abscission or in the upper surface of the bark of the branch. Hence we often find it affirmed that the process of abscission does not depend upon the formation of a cork layer and that this cork layer is to be considered only as a protective layer for the free-lying parenchyma appearing sometimes earlier (before the cleavage), sometimes later.

We owe very extensive investigations of twig abscission to v. Höhnel[7], who has included conifers especially in the scope of his work, and has come to the conclusion that, in them, one cannot speak of any twig abscission,

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1 Th. Hartig, Naturgeschichte d. Forstl. Kulturpflanzen, p. 119. Pfeil, Deutsche Holzzucht, 1860, p. 136. Wigand, Der Baum, 1854, p. 67. Schacht, Der Baum, 1853, p. 305. Lehrbuch d. Anatomie usw., 1859, II, p. 19.

2 Ratzeburg, Waldverderbnis, I, 1866, p. 219 (Plate 28, Fig. 3). Compare Beling and further Roth (Über Absprünge bei Fichten), Bot. Jahresbericht von Just, II, p. 968, 971, and v. Höhnel, Bot. Jahresb. VI, Gonnermann, Über die Abbisse der Tannen and Fichten. Bot. Zeit. von v. Mohl and Schlechtendal, 1865, No. 34. Röse, Bot. Zeit. 1865, No. 41.

3 v. Mohl, Über den Ablösungsprozess saftiger Pflanzenorgane Bot. Zeit. 1860, p. 274 and 275.

4 Röse, Über die "Absprünge" der Bäume. Bot. Zeit. 1865, p. 109 (No. 14).

5 v. Mohl, Über den Ablösungsprozess saftiger Pflanzenorgane Bot. Zeit. 1860, p. 274 and 275.

6 Nördlinger, Deutsche Forstbotanik. 1874, I, p. 199.

7 v. Höhnel, Über den Ablösungsvorgang der Zweige einiger Holzgewächse und seine anatomischen Ursachen. Mitteilungen aus dem forstlichen Versuchswesen Oesterreichs von v. Seckendorff, III, 1878, p. 255. Weitere Untersuchungen über den Ablösungsvorgang von verholzten Zweigen. Bot. Centralbl. 1880, p. 177.

so long as the shedding of living, fresh and sappy branches is meant by it. In conifers, the branch to be shed first dies on the trunk, becoming yellow or brown; it is shed in the usual way only after death, and a cork layer is always formed; in this process, the wood breaks off at a definite place. The abscissed twigs of deciduous trees are shed in a living and sappy condition by means of a parenchyma zone traversing the thick wood but without the assistance of a cork layer.

The age of normally abscissed twigs varies greatly. In Taxodium they are always one year old; in *Pinus strobus,* always three years old; in *Pinus Larcicio,* 2 to 7 year old; in *Pinus silvestris,* 2 to 6 years old; in *Thuja occidentalis,* 3 to 11 years old. It was stated at the outset that spruces and firs are said not to shed their branches. Nevertheless, I remember once having seen fresh spruce shoots with a dismembered surface resembling an articulation.

In deciduous trees, it can be seen clearly that the twigs usually shed are those grown from lateral buds or adventitious eyes which are often weakly, and have grown only to short shoots. Only in poplars and willows and seldom in oaks are long shoots abundantly shed, and then only older ones (branches up to 6 years old). In rare cases the process is observed also in *Prunus Padus* and *Evonymus europaea,* while in other trees usually one year old shoots alone are shed.

Worthy of our attention is v. Höhnel's observation that the *wood of Thuja occidentalis* is weaker where the constriction will appear later, than at any other place. At the place which will later be the cleavage surface, the wood is greatly constricted. The parenchyma cells of the bark enlarge so that a considerable loosening is produced. In *Thuja orientalis* the fleshy branch cushion is lacking, and no regular shedding is found. Meehan[1] found in *Ampelopsis quinquefolia* that the basal internode remains stationary and, in the following year, produces new shoots, which in turn disarticulate with the occurrence of colder weather.

The law formulated for leaf casting may be applied to abscissed twigs:—the *centre of consumption,* which here is the twig, for some reason, *no longer forms the normal centre of attraction* for the undiminished flow of water and an excess of water accumulates accordingly in the basal zone which is still capable of reaction, and anatomically differently constructed. Either the branches, from the beginning, have been more weakly set, or, because of an unfavorable habitat they do not develop so far or, in great summer drought, they have become prematurely ripe or they are rendered incapable of action by cold, etc. In a weak organ, the relative excess of water makes itself felt first at the base. If this organ develops, from the start, with the presence of a large water supply, no shedding takes place. Wet years exhibit little if any twig abscission. The theory held by foresters, that years with much twig abscission initiate good seed years, has its

1 Meehan, On disarticulating branches in Ampelopsis. From "Proceed. of the Americ. Acad. of Philadelphia." Part I, 1880, im Bot. Centralbl, 1880, p. 1005.

foundation in the fact that these are dry years, favoring the maturing of the blossom buds.

Even if twig abscission is of little practical importance in forestry, it is, however, of horticultural importance as a symptom. Especially in the autumn the stem parts of many greenhouse plants are abscissed, as in the bushy Begonias, Melastomaceae, Acanthaceae, etc. They are positive indications of excess of water, and the only means of prevention is to keep the plants dry.

b. Increase of Food Concentration.

Among the phenomena of disease to be discussed in this section, those must be considered in which an excess of water in the plant becomes manifest locally. In this the root activity is not necessarily increased, the accumulation of water is produced rather by a depression of the transpiratory activity of the leaves. Increase in turgor must set in in various organs, or parts of organs, by increased water supply, as has been proved artificially in severed leaves. Consequently, the fact remains to be considered here that the humidity of the air often co-operates decisively. Conversely, in other cases, in which an excess of nutrients is involved, attention should be called to the fact that this excess does not always presuppose an absolute accumulation in the soil, but also occurs when the solvent, i. e., the water, is temporarily present in too small an amount, thereby producing an injuriously high concentration of the soil solution.

The demands made upon the soil solution by each species seem to differ according to the different quantitative proportions in which the various nutrients and other factors of growth participate in the production of one gram of dry weight of a species. In plants, for example, which require much potassium or nitrogen to produce their substance, a high percentage solution of these substances will be necessary for the root. The plants do not die, if the desired high concentration is not afforded them, but they change their mode of growth. They then require, as already proved, much more water just as if they must strive to obtain the necessary quantity of a certain nutrient by an increased absorption of the more dilute solution. In spite of the large quantity of water and substances otherwise offered, the production as a whole is small. A similar cessation of growth is found, if the plants are placed in a too concentrated soil solution. The absorption of water is relatively scanty; the amount of ash, however, large and the production in dry weight small. The excess then is taken up but not utilized, the mineral substances are simply deposited in the plant and may partially be leached out again by water. In water cultures with a high concentration of nutrients the short, gnarled root hairs are sometimes perceptibly covered with crystalline scales. Thus, for example, accumulations of saltpetre may take place in the plant if an excess of potassium nitrate is given. Emmerling[1], by means of experiments, explains very acceptably

[1] Emmerling, A., Beiträge zur Kenntnis der chemischen Vorgänge in der Pflanze. Landwirtsch. Versuchsstationen, Vol. XXX, Part 2, 1884, p. 109.

the processes taking place. He shows that, exactly as with the use of calcium nitrate, potassium nitrate is decomposed by oxalic acid, even in very dilute solutions, in such a way that potassium oxalate and free nitric acid are produced, while oxalic acid does not act strongly on calcium carbonate, since it only coats it with an impervious, thin layer of calcium oxalate. If now the saltpetre in the soil is relatively great in proportion to the acid which a plant species can form, the saltpetre will be taken up, to be sure, but will be decomposed only proportionately to the oxalic acid present, and the free nitric acid is used in the formation of the proteins; the remaining saltpetre is deposited unchanged in the plant.

In our cultivated plants the law certainly holds good, that they all require the same nutrients but in different concentrations, and also that their capacity for enduring the accumulation of various substances is decisive for the success of the cultures. It should not be forgotten here, that neither the absolute amount of nutrients, which is borne without any injury, nor also the quantity of any nutrient proved to be the best (optimum) for production, represents absolutely fixed amounts for any definite plant. Rather, it should be assumed that the need for any definite nutrient changes constantly according to the combination in which the other vegetative factors are present at the moment. *Thus, there is always a relative optimum and maximum for each vegetative factor.* The mode of production and the product,—viz., the plant body,—change according to the momentary combination of the vegetative factors;—thus morphological, anatomical, and chemical analyses give different values for each individual.

Each change in concentration in the same nutrient mixture changes the method of growth and directly manifests itself, under certain circumstances, in the behavior of the root hairs, as stated by Stieler[1]. He found in the growing root hair, with each change in the solution, a change (thickening) of the membrane at the end of the root hair;—under certain circumstances, in fact, a cessation of growth occurs. In aqueous solutions of the *electrolytes,* the root hairs in many plants form vesicular, irregular widenings, and can even crack open at the tip or (rarely) laterally. The non-electrolytes exercise an injurious influence, only if they have a poisonous effect or are present in too high a concentration, which causes plasmolysis. The observation that concentrated *magnesium compounds* can be proved to act *directly poisonously,* is especially noteworthy. This cannot be observed for other nutritive salts even with high concentration.

These investigations confirm my own observations, viz., that, in a highly concentrated nutrient solution, "gnarled or distended" root hairs appear, and thereby indicate that the plant has had to combat difficulties in absorbing its food.

In regard to varieties of grain, the experiments indicate that oats, for example, can suffer from the amounts of nutrients which, for wheat, make

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1 Stieler, G., Über das Verhalten der Wurzelhärchen gegen Lösungen, Dissertation. Kiel 1903. Cit. Bot. Centralbl. v. Lotsy 1904, No. 47, p. 541.

possible only a full production. Thus oats often fail on parcels of land, which have gradually been too heavily fertilized. Measurements of the amount of transpiration show that in concentrated solutions, the plant needs less water, for the production of one gram dry weight, than it does in very dilute ones. From this it is evident that, up to a certain degree, fertilizing signifies a saving of water[1].

The structure and size of the root system is changed gradually by concentration, corresponding to the change in the root hair, already mentioned. Schwarz's[2] experiments with pines demonstrated this very well. He found a gradual decrease in the extent of the roots of conifers with an increase of the nutrient content of the soil, as had already been determined for other plants. Here the relation between the aërial and underground axes was changed. While, in unfertilized sand, the weight of the root system of the pine seedlings was greater than that of the aërial parts, with an abundant supply of nutritive salts the weight of the root system amounted to only one-fifth that of the aërial axis.

Even in cabbage plants, which have been gradually accustomed by cultivation to the highest admissible concentrations, an over-nutrition finally takes place and with it a retrogression in production. Thus kohlrabi plants were found to be especially susceptible to large additions of phosphorus, while they require high nitrogen and potassium fertilization, together with a corresponding addition of calcium[3].

Changes in Meadows.

The method of improving sour and sandy meadows by fertilization, depends essentially on an increase of the nutrient concentration. The acid-loving grasses, or those of sterile soil, which withstand only weakly concentrated solutions, then disappear and our good fodder grasses, demanding higher nutrient content and producing more nutritive substance are established. Very instructive experiments on permanent meadows are found in Lawes and Gilbert[4]. We will cite from them only one example, in order to show that those different grass species gradually prevail in those nutrient solutions, of which they can endure a higher concentration. With the stated fertilizers, the percentages of the various grass species in 100 hay plants were found as given in the following table.

From this table of grasses, we see how the rapidly spreading *Festuca duriuscula* disappears on sterile sandy soil, if the concentration of the nitrate solutions and the mineral substances increase simultaneously. *Agrostis vulgaris* and *Anthoxanthum odoratum* behave similarly, while, conversely,

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1 Sorauer, P., Über Mifsernten bei Hafer. Oesterr. Landwirtsch Wochenblatt. Nos. 2, 3, 1888.

2 Schwarz, F., Über den Einfluss des Wasser- und Nährstoffgehaltes des Sandbodens auf die Wurzelentwicklung von **Pinus silvestris** im ersten Jahr. Zeitschr. f. Forst-u Jagdwesen. January, 1892.

3 Otto, R., Vegetationsversuche mit Kohlrabi etc. Gartenflora, 1902, p. 393.

4 From "Journal of the Royal Agric. Soc. of England" and "Proceedings of the Royal Hort. Soc. 1870," cit. in Biedermann's Centralbl. 1876, II, p. 405.

the heavy feeding plants of our sewage disposal fields, *Dactylis glomerata* and *Poa trivialis*, during the five years over which the experiments extended (the results are given in the table), became more and more abundantly established on the parcels of land strongly fertilized with nitrogen, and crowded out the others. The grass of village streets, *Bromus mollis*, appeared in high percentages only when stable manure had been used, while *Lolium perenne* and *Holcus lanatus* were present everywhere, to be sure, yet spread but little where stable manure was abundantly used.

Species of Grasses	Without Fertilization	Fertilization only with Ammonium Salts	Only with Mineral Fertilizers[1]	With Mineral and Ammonium Fertilizers	Mineral and Double Ammonium Fertilizers	Stable-Manure Alone	Stable-Manure With Ammonium Fertilizers
Festuca duriuscula	13.04	21.42	12.00	2.98	0.79	0.22	0.19
Agrostis vulgaris	8.62	21.29	2.76	11.55	9.15	1.38	0.78
Lolium perenne	8.62	3.39	3.03	11.89	8.60	2.59	2.73
Holcus lanatus	4.97	9.68	4.86	11.06	8.82	2.17	2.01
Dactylis glomerata	1.76	2.27	2.79	5.04	23.58	4.85	16.86
Poa trivialis	1.50	1.61	5.77	12.00	15.47	27.43	29.34
Bromus mollis	0.08	0.15	0.63	2.21	0.93	9.64	12.53
Anthoxanthum odoratum.	3.29	2.41	0.80	0.49	0.10	0.19	0.06

Among other interesting observations of these authors, is the one that the parcels of meadow land, which had remained unfertilized, exhibited great diversity in the families and species growing on them. The grass was short, stemless, and, at the time for cutting, comparatively very green. With mineral fertilizers, the Leguminoseae gained the upper hand, while, in the Gramineae, which, however, showed no especial prevailing genus, the tendency to the development of blossoms was more decided than on unfertilized land. Conversely, *ammonium salts*, given alone without other fertilizers, almost excluded the Leguminoseae, and the Gramineae, therefore, predominated. Festuca and Agrostis reached their highest percentage, and Rumex, Carum and Achillea throve luxuriantly.

If Chile saltpetre alone were used, the effect in general was the same as with ammonium salts; nevertheless, among the grasses, *Alopecurus pratensis* was especially prevalent; and a predominating tendency to leaf production also became noticeable in contrast to the development of the flower stems. Besides the somewhat better developing Leguminoseae, there was a luxuriant development of the little useful Plantago, Centurea, Ranunculus and Taraxacum.

The highest yield and the best development of the grasses was found with stable manure to which some fertilizer containing nitrogen had been

[1] By mineral fertilizers, the authors mean a mixture of super-phosphate with potassium, sodium and magnesium sulfates.

added. The Leguminoseae and other plants disappeared, having been overgrown by the grasses which then ripen more easily than if they have only a nitrogen supply. Stable manure alone also yielded a considerable harvest of *Bromus mollis* and *Poa trivialis* especially, with fewer Leguminoseae, but it left much to be desired in the fineness and uniformtiy of the hay.

If *mossy meadows* are brought under cultivation, the moss cannot endure a concentrated nutrient solution, or, at least, a high concentration of various nutrient salts which require still closer examination. This explains the disappearance of moss from meadows after they have been fertilized with potassium. The same behavior is found for the horsetail (Equisetum) which is said to disappear absolutely after the use of calcium chlorid, and seems, on this account, to be especially sensitive to high calcium concentration.

In contrast to the extreme impoverishment of the meadows, manifested by a mossy vegetation, stands the over-powerful development of grass on the so-called *rankly growing places*. There is an abundant nitrogen fertilization from the excretions of animals and its results are shown by a more luxuriant blade development. According to Weiske[1], the plants had nearly twice as much protein but possibly ¼ less of substances free from nitrogen, than the neighboring plants which had not been over-fertilized. Accordingly, the ash of the former contained more alkalis, magnesium and sulfuric acid. The plants on such rankly growing places, despite their greater volume, remained in an immature condition. With a greater spread of such over-fertilized places, these plants would become more injurious than beneficial. In this they resemble the condition on the sewage disposal beds.

Sewage Disposal Beds.

The increased use of sewage disposal beds near large cities requires special discussion of the injuries unavoidable in this practice. Ehrenberg[2] has recently published his experiences in regard to the Berlin sewage beds.

Aside from the notably increased development of *Plasmodiophora Brassicae,* due to the rapidly repeated cultivation of species of cabbages, he reported also injuries due to animal parasites. Most of all occurred the extraordinary increase of *Silpha atrata,* whereby great areas of beets were completely destroyed. The parasites found over-abundant nourishment in the decomposing organic substances of the liquid sewage and, in the dams and canals, lurking places where they were protected from cold and enemies. The great supply of nutrients also attracted the crows from long distances to the sewage beds on which seeds, as, for example, maize and wheat, were uprooted in whole rows. Rats were another pest.

In addition to the damage done by animal and plant forms, the wind caused more damage here than on other fields. On the Berlin sewage beds

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1 Annalen d. Landwirtsch. 1871. Wochenblatt, p. 310.

2 Ehrenberg, Paul, Einige Beobachtungen über Pflanzenbeschädigungen durch Spüljauchenberieselung. Zeitschr. f. Pflanzenkrankh. 1906.

a large number of fruit trees in full leaf were blown down, in spite of strong stakes, because the earth, which was wet through, did not support the roots sufficiently. This was especially noticeable if a part of the field, with the surrounding avenues of fruit trees, was flooded with liquid sewage.

Sugar and fodder beets, carrots and similar roots irrigated during the growing season, could not withstand liquid sewage about their crowns for any length of time. In a few hours the *leaves began to wilt* and towards evening the petioles became limp. Grains, grass, legumes and other plants without fleshy roots did not react in this way. Probably the wilting is physiological since the scanty root fibers present on each fleshy root cannot draw enough water from the highly concentrated soil solution to make good the loss from evaporation. If the concentration of the soil solution was decreased by the absorption of the soil, the wilting disappeared.

To avoid this, dams one meter wide were built, or the roots were hilled up as they grew and irrigated in the furrows thus produced.

Attention has been called in another place to the change in the growth of grasses. On the Berlin sewage beds, *Lolium italicum* abounds and often is entirely killed if irrigated in winter.

The *softness of the grass,* indicated by its easy decay, is also caused chiefly by an *excess of nitrogen.* On an average, in the years 1900 to 1902, a hectare of the Berlin sewage land received 800 to 1200 kg. Nitrogen[1]. In spite of the very sparse seeding and the widely separated planting the over-fed grain plants are usually inclined to lodge. I had an opportunity to study the process taking place in this lodging of oats on the Berlin sewage beds[2]. In this, a peculiar softening of the leaf tissue, due to bacteria, was noticeable. Regarding the behavior of young seedlings with over-fertilization, I observed in barley, that, in comparison with the normally nourished plants, over-fertilized ones became a darker green, but were backward in growth. Then the tips of the leaves bore greyish yellow spots and finally turned entirely grey; at this time a number of seedlings lodged. Soon after lodging, the part of the stalk above the bend began to dry. But while plants normally drying finally assume a straw color, only the lower leaves in this case became straw-colored and the upper ones dried to a hay green color. Of importance here is also the diseasing of the vascular bundles and the great predisposition of the plants to attacks of fungi[3].

Besides the well-known *delay in the ripening* of grain on sewage fields, Ehrenberg also mentions the change in the proportion between the yield in straw and grain. In irrigated oats the proportion of grain to straw was as 1:3.33, in non-irrigated, as 1:2.88.

Such a "*luxurious growth of straw*" gradually becomes typical, for seven newly grown varieties of barley gave an average proportion of grain

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[1] Backhaus, Landwirtschaftl. Versuche auf den Rieselgütern der Stadt Berlin im Jahre 1914.

[2] Sorauer, P., Beitrag zur anatomischen Analyse rauchbeschädigter Pflanzen. Landw. Jahrbücher von Thiel., 1904, p. 593.

[3] Loc. cit. p. 646.

to straw of 1:1.75, while varieties grown for a long time on sewage beds, showed 1:2.88. Wheat and rye behaved similarly. The amount to which ripening can be retarded in extreme cases, was found for red mountain wheat, which, sown on April 19th, ripened on irrigated fields on the 13th of September, but on non-irrigated, on August 24th. There was then a difference of 20 days.

Mention is made in another place of the disadvantageous effect of chlorin compounds on the starch content of potatoes, and on other plants.

The *"coating with ooze and mud"* is the most important injury in sewage disposal beds. *Liquid sewage* contains, besides great quantities of sodium chlorid and other salts, many organic substances especially pieces of paper, coffee grounds and the like. Six investigations of Berlin sewage in 1902, gave on an average:

Organic Substances	0.030 per cent.
Potassium	0.006 per cent.
Sodium	0.022 per cent.
Sulfuric acid	0.006 per cent.
Chlorin	0.020 per cent.

The pieces of paper and the organic substances dry up on the beds into tough, thin, flat cakes, decomposing only with difficulty because of their fatty content. Soaked with salts and organic substances, these form the ooze, which acts detrimentally to the soil. The high content in salts will easily cause a leaching of the calcium through an exchange of bases.

Analyses[1] prove that, on sewage beds covered with ooze, *calcium* is actually carried off. The calcium content amounted in

	upper surface	sub-soil
Normal soil	0.153 per cent.	0.031 per cent.
The same soil, but covered with ooze	0.122 per cent.	0.048 per cent.

An application of calcium is, therefore, desirable in soils covered with ooze, since its action improves the soil physically.

The disposal of the above mentioned papery flat cakes, which may choke young plants, especially grasses, will have to be undertaken first of all by harrowing, tearing and removing the rags. Nevertheless, in planting the fields, great quantities get on to the soil and have an injurious effect. The enrichment in organic substances, due to the ooze, may be recognized from the loss when heated:

Normal soil contained (in a friable condition)	1.994 per cent.
The same soil, covered with ooze	2.418 per cent.

Vegetative experiments in pots showed that an admixture of ooze always arrested growth, and an addition of quick lime did not overcome this retardation. The arrestment in development did not show itself in the appearance of positive symptoms of disease, but only in the delayed sprouting

[1] Backhaus, loc. cit. p. 69 and p. 114.

of the seed and general depression in growth. The explanation of the phenomenon should be sought in the physical domain. The ooze which is very impervious to water and air
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THE SCURVY

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Scurvy or
of flatly spread,
bark-like spots
fleshy underground root, or storage tuber. As long as such a bark-like cleft remains superficial the disease is called *"surface scurvy."* If, on the other hand, the injured places deepen rapidly becoming grooves or holes, the disease is called *"deep scurvy."* In certain cases warty outgrowths appear on the wounded surface, and this condition has been distinguished as *"knotted scurvy."*

Fig. 52. Carrot diseased with deep scurvy, seen from the most diseased side of the root.

Fig. *A*. *l*, l^1 and l^2, vascular bundle rings arranged in terraces; *g*, holes in the tissue with tinder-like edges. *k* tuberous parenchyma outgrowths on the carrot bend, which may be indicated as the overgrowth tissue of the scurvy wound. *s*, initial stages of the scurvy which extend downward along the root groove (*W*), *r* outer edge of the scurvy hollow *c*, its deepest part. Fig. *B* Cross-section of the carrot near the center of the deep scurvy (*c*) Vascular bundle rings destroyed by the scurvy *l* l^1 and l^2 which extend outward like terraces from the deepest part of the wound *l* shows the poor formation of the outer vascular rings.

Besides sugar and fodder beets, potatoes suffer most frequently: also roots of the Umbelliferae, such as celery, carrots, parsley, etc.; more rarely the fleshy roots of cabbage plants. This condition is characterized by the destruction of the cork layers. For some time they are replaced again and again by the underlying tissues. Fig. 52 illustrates a sugar beet suffering from "zonal deep scurvy" or "girdle scurvy," the worst form of this disease. The beet is 7 to 8 cm. thick at its head, but is circular only at the top; while on both sides where the roots grow, there is a considerable flattening which disappears again toward the lower end. The flattened sides are depressed like troughs and the centre of the trough is possibly 6 cm. away from the cut surface at the head of the beet. The inner surface of the trough is wavy because, around the very deep centre, the different layers of the beet flesh rise like terraces above one another towards the outer edge in more or less clearly defined zones.

The consistency of the tissue at the edges of the trough is tindery, scurvy-like, i. e. fissured and the fissures traversed by tube-like passages, which initiate a fibrous decomposition of the substance. The passage-like fissures are lined with brown, corked, jagged pieces of tissue, whose surfaces show a peculiarly grainy decomposition. In spite of the deep decomposition at the place attacked, we find that the beet retains the ability to react, for the edges of the various rings of vascular bundles, because of a new cell formation, curve out like ramparts after the injury.

That the growth of the beet at the scurvy places may previously have been somewhat arrested is evident from the fact that, on the injured side of the beet as well as on the opposite side, the different tissue rings are smaller than on the other sides. If cross-sections of the diseased plants are treated with sulfuric acid, it is found that beneath the brown, dry, gradually decomposing tissue layers, which have turned to cork, the intercellular substance of the apparently healthy root flesh assumes a yellowish, wine-red to bright carmine tone. Often some duct groups also seem to be provided with solid balls, or stoppers, which assume the same color when treated with sulfuric acid. Later the intercellular substance is found to be broken up and finally begins to decompose into a grainy slime. To the naked eye the whole process seems a form of dry decomposition.

As already mentioned, this form of scurvy which extends so deep into the flesh of the beet, is less frequent. We usually find much flatter, bark-like fissures, occurring in circular areas, and often showing that they have appeared in a rather early developmental stage of the beet, but later have stopped spreading. It is worth noting that, in the zonal deep scurvy, the head of the beet does not seem to be attacked, but the disease becomes visible first at a certain distance below this, in the soil. In too deeply planted beets the first traces of scurvy are often found at the base of the petioles. Very similar phenomena are noticed also in potatoes, carrots, etc. In potatoes, it has been observed that the scurvy formation extends out from the lenticels. If we examine such a lenticel, we perceive without diffi-

culty how fit a point it is for parasitic attack. Here, under the skin, formed of plate-like cork cells (*k*) (in the subjoined Fig. 53), we find the first stages of lenticel formation beneath the stomata in the form of irregular cells, poor in contents (*a*). Since this cell formation extends further and further backwards and the cells first formed take up water, swell and rupture the corky cortex, a lenticel is produced which now gives rise to scurvy. From it the loosened cork cells (*f*) push out in the form of a whitist, moist meal. These cells decay, and the process of decay is continued further inward so that the close pressed, still connected rows of immature cork cells (*v*) must be sought deeper and deeper in the interior of the tissue. Here the starch (*st*) disappears from the tissue surrounding the cork cells. Continued moisture will develop very similar-conditions in

Fig. 53. Lentical formation on the potato skin.

other underground parts of plants. In this process the cork mantel, which has previously acted as a protection, is seriously loosened and broken apart.

The scurvy disease has recently been considered to be parasitic and usually is described as due to bacteria. Therefore, it is also treated in the second volume of this manual[1]. But there it is emphasized, that the cause is ascribed to very different organisms, by some, to bacteria, and by some to fungi. On the one hand, it is stated that these organisms should be considered as wound parasites, which cannot attack the uninjured cork layer (Krüger), while, on the other hand, inoculation experiments on immature organs have been carried out successfully under special circumstances. (Bolley). It must also be added here that a great many practical experiments have determined beyond question that, as already mentioned, certain substances contained in the soils favor scurvy. This explains the possible

[1] See Beet scurvy, p. 46 and Potato scab, p. 75.

connection of the scurvy disease with parasitic organisms, which, nevertheless, are not specific scurvy organisms. It is much more probable that, in beet soils, saprophytic species, which are generally present, are able, because of definite changes in the composition of the soil, to attack weakened, old beets, or tender young ones. The fact that the healthy vascular bundle rings are more slender where scurvy began, i. e., their growth in breadth has been retarded, proves that the beet has undergone arrestment during the time of the scurvy disease.

Supported by Bolley's inoculation experiments[1] which prove that beet scurvy and potato scab are due to similar causes, we will take up the main question, viz., what conditions have been determined practically as favoring or causing scurvy. It is well known among agriculturalists that marling the field results most frequently in an attack of potato scab. The yellow marl, which contains magnetic oxid (Fe_2 O_4) is said to be the most dangerous. Frank has conducted cultural experiments[2] to determine the problem. Scurvy is produced on unsterilized soil, but not on sterilized, even when loamy marl is added to it. As shown by experience, meadow ore, street sweepings, sewer muck, fresh animal manure, liquid manure and Chilean saltpetre all favor scurvy, which fact enforces the decision, that *an alkaline reaction* affords the most favorable conditions for the development of scurvy organisms. Bolley[3] also arrives at this conclusion. His experiments show that the scurvy bacteria which he used develop most rapidly on neutral or basic nutrient soils. Frank's comparative experiments prove that moisture acts favorably, and Bolley emphasizes the observation that light, sandy soils, as a rule, yield smooth tubers. Frank's results seem to contradict the observation that a good deal of scurvy can be found in some places in hot, dry years.

These apparent contradictions are explained by Thaxter's investigations[4]. He distinguishes between organisms causing the deep scurvy and those causing superficial forms and emphasizes his conclusion that a neutral reaction seemed most favorable for the organism which he cultivated. Slight alkalinity, however, like slight acidity, seemed to have a retarding effect. In his experiments young tubers were attacked at any place, older ones on wounded surfaces and especially on lenticels, while nearly ripe tubers were entirely free.

All scurvy organisms, therefore, do not seem to require the same conditions. In common, however, they prefer lenticels and young organs with a delicate cork covering. In beets, the places where the rootlets arise are especially suitable as points of attack for the micro-organisms. These places become very much broken in wet soils, and this fact explains the assertion that moisture favors the development of scurvy diseases. Wet,

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1 Bolley, H. L., A. disease of beets, identical with deep scab of potatoes. Gov. Agric. Exp. Stat. f. North Dakota. Bull. 4, 1891.

2 Kampfbuch gegen die Schädlinge unserer Feldfrüchte. 1897, p. 177.

3 Zeitschr. f. Pflanzenkrankh. 1901. p. 43.

4 Thaxter, Roland, The Potato Scab. Fourteenth Annual Report of the Connecticut Agric. Exp. Stat. 1890.

heavy soils are aërated with difficulty and if substances are present in the soil, which require large amounts of oxygen, they take it from the living plant when a sufficient amount is not found in the soil. Refuse, sewage, animal manure, ferrous oxid compounds, etc., must be considered as substances which require a great deal of oxygen. We find examples where a piece of land fertilized with stable manure yielded scabby potatoes, while unfertilized land surrounding it yielded a crop free from scurvy[1].

However, in the decomposition of sewage and other animal refuse, injurious sulfur compounds are produced in the soil, which will naturally act poisonously on the root system and yet favor certain groups of bacteria. As soon as such processes set in, the scurvy bacteria, which prefer neutral or alkaline soil, will thrive.

Such conditions may also be produced in clay soils in times of intensive heat and drought; or they can be brought about by the addition of marl containing iron. In this way might be explained the appearance and often the annual repetition of the scurvy, which may appear after marling but does not always set in. All the above named factors favoring scurvy can actually develop it in certain cases and not in others. The good effect of lime, already observed in many cultural experiments[2], may be explained by its characteristic flocculating action in heavy soil, with a consequent improvement in physical texture. The soil becomes warmer, more porous, more easily aërated, while the animal manure is more protected from unfavorable decomposition. The easily aërated sandy soils, which do not long contain highly concentrated soil solutions, are usually free from scurvy. Therefore, the various substances, said to favor scurvy, are not injurious in themselves but only in certain combinations, which direct soil decomposition into unhealthy channels.

We have been led to the point of view here expressed by our own experiments[3], which were intended to answer the question, as to whether scurvy can be retained constantly in the soil and can spread there. The result was negative. In the two successive experimental years not only the tubers obtained from healthy seed, but, with a very few exceptions, even those originating from scabby potatoes were healthy. Thus it is clear that the condition of the seed does not necessarily determine that the scab disease will be present in open land, and so the much recommended sterilization is unnecessary. The recommendations for combatting the disease must be based on a change in the constitution of the soil and especially on the avoidance of substances which favor scurvy. In regard to the oft-asserted injuriousness of lime, my experiments have proved that tubers, some of which were brought directly in contact with the lime, remained perfectly smooth skinned and healthy. Recently, substances have been introduced

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[1] Arb. d. D. Landw.-Ges. Jahresbericht d. Sonderausschusses f. Pflanzenschutz 1904.

[2] Krüger, Fr., Untersuchungen über den Gürtelschorf der Zuckerrüben. Zeitschrift d. Ver. d. Deutsch. Zuckerindustrie. Nov. 1904.

[3] Zeitschr. f. Pflanzenkrankh. 1899, p. 182.

into trade which are said to increase the reaction of the soil (for example, *sulfarin*).

In connection with scurvy diseases of edible roots, we would like to call attention also to similar phenomena on smooth barked young trees, which have not as yet been studied. Lindens, elms, oaks, etc., on certain kinds of soil (i. e. moor-soil) had round, rough splits in the bark, which increased greatly in extent adjacent to the adventitious buds or shoots. This *bark scurvy* is frequent near large cities, where the base of the tree is exposed to débris of all kinds.

Another phenomenon found in barley and wheat, which should be included in this group, is *"spotted necrosis,"* i. e., the appearance of deep, dark reddish brown, dying spots at the tip and along the edge of the grain leaves. Up to the present, I have found the disease most extensively in heavy, clayey, or moor soil, which had had abundant potassium fertilization and also in regions with a deposit of ashes.

Progressive Metamorphosis.

While, in the cases already discussed in this chapter, we have emphasized as the common characteristic of all the phenomena, the influence of unsuitable concentrations of the soil solution, because of which the plant suffers, we will now consider the cases in which the plastic building substances have been increased out of proportion to their utilization. Here, too, an excessive supply of nutrients in the soil does not give rise necessarily to this condition, but, for various reasons, a disturbance in the equilibrium in the formative direction of the individual may occur, that is to say, *a change in the utilization* of the plastic food materials.

Examples of this are those phenomena grouped under *progressive metamorphosis,* such as the transformation of leaf organs into a morphologically higher developmental form. Teratology classifies such transformations under the heads *"petalody"* and *"pistillody,"* i. e., cases in which the calyx bracts become petal-like, or parts of the corolla assume the character of the stamens, or the organs actually belonging to the androecium circle are changed into carpels. Numerous examples of petalody are furnished by the cultivated forms of our Primulae and Ranunculi. We find the best instances of pistillody in the poppy (*Papaver somniferum*). In this plant, as in the different varieties of cabbage, long continued cultivation has so disturbed the morphological rules, that the organs tend to transformation. A most interesting case may be found in the poppy heads which, at the base, bear a circle of many small, woody primordia of smaller heads (stamens which have been changed into carpels). In double tuberous Begonias, tulips and other Liliaceae, specimens are found in which the stamens have been transformed into carpels with seed primordia. Related to this are the phenomena of the *"cone malady"* in conifers, especially in pines, as illustrated in Fig. 54.

In the majority of cases, the cones at the base of an annual shoot lie close together and remain smaller than normal ones, but yield seeds capable of germination. The production of such cones, instead of staminate flowers, points to a local excess of concentrated, plastic food material. Borggreve[1] has made a corroborative observation. He found, the year after transplanting several spruces, possibly 15 years old, in the Botanical Gardens at Bonn, that the terminal shoot had been transformed into a pistillate inflorescence.

If an excess of plastic building substances participates in this, so that the various leaf members of a blossom retain their form, but the axis is lengthened, we speak of the disunion of parts of the blossom normally united as *apostasis*. The calyx, for example, then appears separated from the corolla by a long internode, the corolla in turn from the stamens, etc.

The most perfect form of over-nutrition of the blossoms is found in the so-called *"Rose-Kings,"* i. e., in the roses in which a new blossom springs from the center of an older one,

[1] Forstliche Blätter 1880. Vol. 17, p. 246.

Fig. 54. Cone disease in the Scotch pine. (After Nobbe.)

or new blossoms appear laterally. We term such cases *proliferous shoot development* (*proliferation*). Unusual buds arise inside of one blossom or of one inflorescence.

Fig. 55. Sprouting pears.

Such buds sometimes develop into blossoms, sometimes into leafy shoots. If such an adventitious bud stands in the centre of a blossom, so that the axis of the flower appears to end in it and can be continued only by the development of this bud, we call such a proliferation *diaphysis*. If, on the other hand, the adventitious bud appears in the axil of any member of the inflorescence, or the bracts, the formative variation bears the name

of *axiliary proliferation,* the appearance of buds within the flower (*ecblastesis*). Sprouts in the centre of the blossoms are more frequent than those in the axils, a circumstance probably connected with the fact, that all shoots, which form the direct continuation of the erect axis, obtain water and nutrition more easily than do lateral branches. In favor of this is also the very rare occurrence of proliferations in flowers which stand isolated in the axils of leaves.

The *doubling of blossoms* in the Compositae consists, as is well-known, mostly in the change of the normally tubular labiate flowers into brightly colored ligulate flowers (ray florets). Proliferation in the Compositae has often been observed, when, instead of the separate florets, a whole head is produced at the base of the inflorescence. Thus Magnus[1] reports specimens of *Bellis perennis* which had numerous, stemmed secondary heads around the edge of its heads. The same phenomenon has been observed at times on *Crepis biennis,* L. as well as on *Cirsium arvense* Scop. Everywhere the individual florets were so developed that they had a more or less long stemmed axis, often provided with dry, membraneous leaflets and crowned by a small but perfect flower head. In fact, on the edge of each secondary head, tertiary heads and even heads of later orders may develop.

Similarly *sprouts* from phanerogamic *fruits* are not rare. The best known examples are found in our pomaceous fruits and, of these, more often in pears than in apples. We give in Fig. 55 an illustration of sprouting pears, in which one or more secondary fruits develop on the primary fruit. This phenomenon may be explained by considering the fruits of our pomaceous fruit as twigs, of which the bark has developed extraordinarily. Usually, the tip of the twig ends in the carpels. These develop into a core and bear the seeds inside this core. The bark of the twig swells, depressing more and more the terminal blossom above the seed primordia and becomes the flesh of the fruit by material changes and cell-elongation. As in the proliferation of the rose, a pear blossom may also develop a secondary blossom in its centre, in which the small axillary crown between the embryonic carpels elongates; the carpels are pressed apart, or do not develop at all. This secondary blossom matures into a twig, sprouting from the firts pear. This develops a blossom at its tip or, without it, swells out like a top, thus producing a second pear on the first one. If these twigs do not develop sexual organs,

Fig. 56. Larch cone with growth of the axis continued. (After Nobbe.)

[1] Sitzungsber d. Bot. Ver. d. Prov. Brandenburg XXI, 1879. Sitz. v. 28. Nov.

the monstrous pears have no core. If the proliferous axis of the fruit divides, lateral, smaller pears sprout around the central one.

In apples, the ability to sprout often extends only to some branches of the vascular bundles in the fruit. Then a knot swells out at the side and can increase to a small secondary fruit. If the lateral sprout develops and produces an actual bud, we find two cores lying diagonally above one another. This case bears great resemblance to *double fruits* which arise from the union of two separated, laterally placed embryonic flowers. A simple case is the development of a dormant leaf bud on the unthickened part of the fruit, i. e., the stem.

In conifers, proliferation is found in the continued growth of the cone axis into a needled branch; this may be found most often in larches (see Fig. 56).

Among the phenomena in which an excess of plastic food material is manifest, belongs also the occurrence of leaves at places on the axis which normally should be leafless, *Chorisis,* and the increase of the leaf organs in a node (*Doubling, Dédoublement*) as also the multiplication of parts of a compound leaf (*Pleophylly*). The most common example of the last case is the *four-leafed clover.* Tammes[1], in a recent study of this case, mentions that De Vries, by continued selection, has created a race, the individuals of which possess four to seven leaves. This is also a very good example of the way in which phenomena of over-nutrition, once produced accidentally, may become hereditary. We referred to this point also in treating of fasciation. In the clover, individual veins and even the midrib seem more vigorous and are divided, at times extending even into the petiole. Then each part of the divided petiole bears leaflets at its tip. Pleophylly also deceases on the branches of the second, third and fourth order in which the supply of nutrients decreases in contrast to the first produced, vigorous axes. We find less striking examples in all plants. Leaves which display especially strongly developed leaf surfaces and then a forking of the different veins are found everywhere on the branches most favorably located for the supply of nutrition.

Such luxuriantly developed forms are found most often in the so-called *sprouting of the stock,* i. e. sprouts growing from dormant and adventitious buds on the stumps of felled trees (for example, Populus and Morus). The size proportions usually far exceed the average and the leaf forms often vary from the type, even to unrecognizable forms. In these cases the newly produced shoots have the whole store of reserve substance of the tree stump at their disposal, which causes their enormously increased growth.

As related phenomena we will also name here the *witches-broom* which we may pronounce a "*twig-malady.*" The accumulation of the plastic food material in various places in the branch, which gradually seeks utilization

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1 Tammes, Tine, Ein Beitrag zur Kenntnis von **Trifolium pratense quinquefolium** de Vries, Bot. Zeit. 1904, Part XI, p. 211.

in a proleptic bunched formation of branches may be produced, in the majority of cases, by parasitic stimulation. As a rule, the abnormally formed axes deviate structurally from normal ones[1].

Further, there belongs here *retrogression to the juvenile form*[2] in trees which sprout vigorously after great injury. The so-called *rosette shoots*, as shown for a pine in Fig. 57, result from local over-nutrition, due to the fact that the trees have previously suffered very great loss of foliage (usually from the attacks of caterpillars). The mobilized building substances, which have thus lost their province of nutrition, now stream toward the dormant buds, lying between the normal clusters of needles or more clearly recognizable in the form of weak whirls, and cause them to sprout. Instead of clusters of needles, simple broad, sword-like needles with serrate edges are then produced. In their axils, as shown in the figure, the normal short shoots (clusters of needles) may again be formed.

Fig. 57. Rosette shoot of a Scotch pine.

In the axils of the simple sword-like needles are shown the short shoots with double needles. (Enlarged.) (After RATZEBURG.)

If we consider these cases as a whole, we perceive at once a feature common to all. It is the excessive presence of building material in one part of the axis. Indeed, by over-nutrition, organic substances, actually newly formed by the leaf apparatus, are placed at the disposal of a part of the axis, or an accumulation of the structural material is produced locally since the mobilized reserve substance does not find its normal utilization due to some injury such as attacks of caterpillers, pruning, storms, etc. If this excessive material reaches the existing primordial organ, it becomes manifest in the increased development of the normal form, or, within the compass of progressive metamorphosis, of other organic forms. If the structural substances reach a vegetative point, additional organs are formed. Each vegetative point is always the product of the food at its command. It retains its distinctive morphology only as long as the nutritive process remains the usual one. If the amount of structural material is increased, the vegetative point forms additional primordial organs, thus changing the laws of the leaf arrangement, determined by heredity. New normal, vegetative points may develop in the form of buds. There are, therefore, no steadfast characteristics in an organism and cultivation constantly changes the inherited structural type.

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[1] Compare Zang, Wilh., Untersuch. über die Entstehung des Kiefernhexenbesens. Ber. d. Kgl. Lehranstalt f. Weinbau usw. Geisenheim 1905, p. 235. Abundant material has been furnished recently in the Naturwiss. Zeitschr. f. Land- u. Forstwirtschaft.

[2] Diels, L., Jugendformen und Blütenreife im Pflanzenreich. Berlin 1906. Gebr. Bornträger.

Pressure of the Buds (Blastomania A. Br.).

In the preceding section the so-called *"sprouting of the stock"* has been considered. The phenomena are observable everywhere where large trunks of poplars, oaks, beeches, chestnuts, etc., have been felled. On the cut surface of the stump a callus arises from the cambial zone and numerous adventitious buds are formed on this. The various processes of propagation by *"leaf-cuttings"* of Begonias, Gesnerias, etc., show that new buds may be produced on the cut surfaces of herbaceous stems and leaves. The peculiarity of *"viviparity"* should be presupposed as equally well-known, i. e., the development of new vegetative buds from an uninjured leaf blade during the normal course of development (*Asplenium, Bryophyllum,* etc.). Frequently observed, but abnormal cases, are similar formations of buds in *Cardamine pratensis, Drosera intermedia, Arabis pumila,* etc. Duchartre found small leafy shoots growing out of leaves of *Solanum Lycopersicum.* Braun observed such excessive formation of adventitious buds on the leaves and especially on the stems of the cultivated forms of *Calliopsis tinctoria.* For example, he could count about 300 on a piece of stem possibly 20 cm. long[1]. Similar cases have also been observed on other plants[2], and I found specimens of *Pelargonium zonale* and *P. peltatum* with disc-like, fleshy outgrowths at the base of the stem which were entirely covered with little buds. Individual, more vigorous specimens developed to such a point that even very small leaves could be distinguished; the majority of the buds died because of mutual pressure. A similar fleshy cushion was formed by a *Dahlia variabilis* tuber which had been forced in a propagating case, in order to develop new eyes from the base of the stem. The shoots were cut off immediately for use as cuttings, whereupon the growing stumps developed new lateral shoots from their basal buds, which became more and more numerous but increasingly weaker. In this way a ***herbaceous goitre gnarl*** was produced.

The Goitre Gnarl of Trees.

With the rarely occurring bud accumulation in herbaceous plants, above mentioned, there is naturally connected a formation of goitre gnarls in trees, which, with few exceptions, are produced when the growth in length of normal branch buds is prevented, thus inducing the sprouting of new lateral buds in their stead. The shoots from such buds stand closer, the nearer they are to the base of the branch from which they arise, because the internodes are shortest there. If the tip growth of such shoot primordia is limited by injury, or some other cause, such as mutual pressure, they again develop lateral shoots.

The illustration from a trunk of *Acer campestre* in Fig. 58 gives a fine example of a goitre gnarl. After the noticeably thick bark had been

1 Braun. A., Über abnorme Bildung von Adventivknospen am krautartigen Stengel von **Calliopsis tinctoria,** Dec. Verh. d. Bot. Ver. d. Prov. Brandenburg, XII, p. 151.

2 Magnus, P., Verh. d. Bot. Ver. d. Prov. Brandenburg, XII, p. 161.

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Fig. 58. Peeled, gnarled growth of the maple.

removed, the wood showed the spike-like processes of the dead bud cones. The surface view is given at *a*; at *b* the cross-section of the spike-like wood cones with the medullary parenchyma indicated by the darker inner circles.

Similar structures appear in very different tree genera and at will in places on the aërial axis as well as in the buds of the root stock,—but here more rarely. The places exposed by the removal of branches are especially preferred. Here the latent and adventitious buds, accumulated at the base of the branch, begin to develop into small shoots. The wood elements,

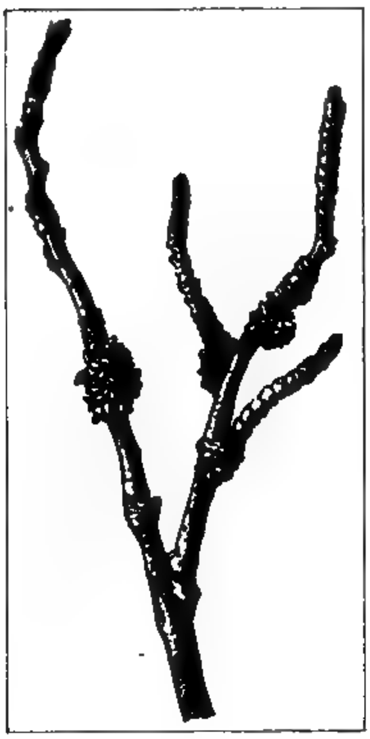

Fig. 59. Formation of gnarls on the branches of **Malus sinensis.** (After Kissa.)

Fig. 60.

Cross-section through a gnarl cushion.

It is seen that the central part of the individual spikes of the gnarl is produced by a broadening of the medullary ray of the branch axis. (After Kissa.)

arising from the cambium of the trunk, take a serpentine course around the bud cones, because they are prevented by them from extending through the cambium. The plastic food material is, therefore, not conducted so readily towards the base of the trunk. But the economy of the tree suffers little, as the gnarled swelling usually occurs on one side of the axis, so that the opposite side lies free and remains constantly accessible for normal nutrition.

Nevertheless, normal branch primordia may not always be assumed as the points of departure of gnarl formation. There are also cases in which the spikes of the gnarl arise from *excrescences of the medullary rays.* One

such case is treated in a study by Kissa[1] on gnarl formation in *Malus sinensis*, which he conducted under my direction. Fig. 59 shows a branch of gnarl cushions, which have sprouted chiefly from the parenchymatous base of a small fruit shoot.

In cross-section, it is seen that the conical spikes represent wood cylinders, of which the central tissues have arisen from broadened medullary rays. This kind of medullary ray (Fig. 60) is either primary or is produced only in a later annual ring. The wood layer of the spike is a continuation of the wood ring of the mother branch. As in a normal lateral axis, the spike of the gnarl is covered by its own bark and has also a well developed cambial layer. Just like a normal branch, the spike of the gnarl ramifies (Fig. 60 *hm'*) and lengthens by apical growth. But not one of these axes at any time bears the primordia of leaves or buds.

The differentiation of the tissue of the spike of the gnarl takes place in the very first developmental stages inside the bark of the mother branch, which at first appears to be only swollen. This swelling is produced from the upward forcing of the bark by a number of especially strongly developed medullary rays, provided with *meristematic tips*. By the further apical growth of these structures, the bark of the mother branch is finally ruptured and the spikes of the gnarl, covered with their own bark, now appear as independent structures. But growth in length soon ends since the bark cap and the underlying meristematic layer dry up. Instead of an apical growth, a basal, lateral sprouting now takes place in the different gnarl spikes in the interior of the mother branch.

Fig. 61. Longitudinal section through the spikes of a gnarl. (After Kissa.)

In Fig. 60, the cross-section of a branch covered with gnarls, we see that the medullary rays forming the pith of the spikes are mostly primary, and, therefore, arise from the pith of the mother branch. *sp* indicates the

[1] Kissa, N. W., Kropfmaserbildung bei **Pirus Malus sinensis**. Zeitschr. für Pflanzenkrankh. 1900, p. 129.

spike; *m*, pith; *h*, wood; *r*, bark; *c*, cambium; *mst*, medullary rays of the mother branch; *hm*, wood layer; *rm*, bark layer of the spike; *n*, meristematic cap of the spike; *hm'*, *rm'*, wood and bark of the lateral sprouts of the gnarl cone; *h'*, second annual ring; *h''*, third annual ring.

Fig. 61 is a highly magnified longitudinal section through a spike of a gnarl lying within the bark of the mother branch. *Ph*, indicates the phellogen; *k*, the cork layer; *Pc*, the collenchymatically thickened cells; *Pr*, the parenchyma of the primary bark of the mother branch, of which the innermost layers begin to be filled with starch; *St*, starch; *Abp*, dead layer of parenchyma cells of the primary branch bark; *M*, meristematic tip of the spike; *A*, cells of the wood layer of the gnarl cone with their pores (*Por*); *c*, cambium; *B*, bark of the spike.

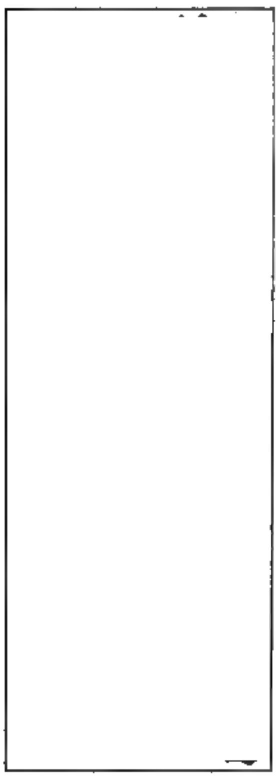

Fig. 62. Bead-like formation of gnarls in the black currant.

Therefore, the cone mantel (*Abp*), composed of the shaded cells, forms the boundary between the spike primordia and the mother bark of the twig and may be clearly recognized as the axial cylinder, since the wood layer (*A*) is covered with its own bark tissue (*B*) while, between both, the cambial zone (*c*) becomes recognizable. The wood cylinder is composed chiefly of very porous parenchymatous wood (*Por*). The bark tissue abounds in starch. The young spike is lengthened by the apical growth of its meristematic cap, and gradually compresses the adjoining cells of the mother bark into a yellowish layer (*Abp*). Above this dead cell layer, the mother bark is still perfectly healthy and dies only if ruptured by the gnarl cone.

In the above statements, we have paid special attention to the structure of the completed gnarl cone, and will now turn to the processes of broadening the medullary rays, which initiate the formation of the gnarl cone. I have studied one such case in *Ribes nigrum*[1].

Fig. 62 *h* shows the accumulated beady gnarls, up to one millimetre in height, which lie side by side, or partially over-lapping. In the cross-section, Fig. 63, is seen the radiation of the wood ring of the branch, in fan-like or feathery subdivisions, into the body of the gnarl which in this case is not conical, as in *Malus sinensis*, but resembles a spherical wart.

Fig. 63 gives at *B* the longitudinal section, at *A* the cross-section of a gnarl wart. *D* is the normal axis of the branch with its pith body (*m*) and wood ring (*h*), which now seems cleft by the excrescent medullary rays

[1] Sorauer, P., Krebs an Ribes nigrum. Zeitschr. f. Pflanzenkrankh. 1891, p. 77.

(*mst*). These medullary rays form the point of departure for the fan-like gnarl formations (*sp*) which, in later development, display a central wood body (*kh*) and a distant bark layer (*r*).

A cross-section through the branch at such a warty place shows (Fig. 64) that the wart represents a conical outgrowth (*k*) of the inner bark, which has ruptured the outer bark layers, but is still covered by them, like lips (*l*). The edges of the lips are dead, and a mycelium is usually found in the depressions. This grows out into the outer, browned and dying or already dead cells of the primary gnarl cone (*p*). If we trace back the excrescent tissue which, towards its base, possesses a wood layer composed of slender, reticulately thickened vascular cells, passing over into the normal wood ring, it is found to be only a simple outgrowth of a medullary ray.

Fig. 63. Cross-section through a part of a twig covered with gnarls.

Fig. 64 illustrates an advanced stage of the medullary ray outgrowth of a branch at the end of the first year (the year of its production); the left side still shows the normal bark structure; at *ak* are the suberized

Fig. 64. Cross-section through the bark of the black currant; healthy tissue at the left; at the right a continued outgrowth of the medullary rays.

remnants of the outermost bark layers shed in the course of the year of its production, which contain scattered crystals of calcium oxalate. These remnants are still connected in places with the discolored, uninjured cork lamellae (*gk*) which enclose the twig, like a firm, uniform girdle. Below

the cork layer lie the collenchymatically thickened bark layers ($c\ o$); these border on the parenchyma containing the chlorophyll (*chl*) which is seen separated into zones by tangential calcium oxalate bands (o, o^1, o^2). The normal bark of the healthy branches also not infrequently has tangential cavities along these bands of crystals, produced by the tearing of the cells which remain thin-walled and contain small deposits of calcium oxalate, so that some of the crystals appear to be lying free near the edges of the cavities.

In the autumn of the first year, the phloem rays may be seen to extend as far as the first oxalate band (o). Adjacant to these rays, as is usually the case in our woody plants, the cambial zone (c) curves outward over the wood, and then in again, like a bow. This shows that the medullary ray assists in the radial extension of the axis, just as the pith cylinder itself causes the longitudinal stretching.

Fig. 65. Medullary ray in the first stages of the gnarl formation.

On an average the normal medullary ray (m) retains, inside the bark, the number of cells last formed in the wood and its extension in the bark then depends only on the greater distension of the individual cells. Near the excrescence, however, medullary rays are often found of which the cells have increased in number (m') but have kept essentially their radial, normal elongation. An extraordinary cell increase finally takes place in the ray of the excrescence and the cambial zone curves abruptly outward.

This is best seen in the comparatively few cases in which the medullary rays begin with the formation unilaterally of excrescent tissue, as shown in Fig. 65. In this figure m indicates the cells of the medullary ray within the wood; c the cambial zone which at the right side rises towards the wood (h) and sinks back at the left side over the wood; nr is the normal side of the bark ray, which pushes against the thick-walled bark parenchyma (p) and, in caustic potash, is clearly differentiated from its surrounding tissue by its yellower color. At o are indicated the very thin-walled small cell rows containing calcium oxalate; here, near the cambial zone, the walls of these cells show a peculiar granular consistency as an indication of their approaching decomposition. Such a granular, slimy decomposition of these cell bands and the movement of the calcium deposits to the edges of the cavities thus produced is also found in the normal bark. On the excrescent side (wr) of the bark ray, of which, the cells turn a still darker yellow after treatment with caustic potash, than do those of the normal side, and not infrequently display a distinct knot-like swelling of the walls, the cambial zone turns abruptly outward (c') and indi-

cates that it will curve outward like a cap in the mature tissue of the excrescence.

This conical elevation of the cambial zone is visible in Fig. 64 *wc*. It forms also an apical region, which, however, does not lie at the outermost tip of the excrescence but always remains covered by bark tissue, which dies from the outside inward until it reaches the meristematic tip of the excrescence cone.

The apical as well as the basal region of the meristematic zone of the gnarl cone begins to develop shoots in the following year. Successful sections, showing the full course of a medullary ray, demonstrate that the formation of the secondary axes takes place repeatedly in the same way in which the primary gnarl cone was produced,—viz., by the outgrowth of part of the medullary ray extending through the bark.

If the structure of the internodes is traced from the spot already recognizable as the primordium of a gnarl towards the younger parts of the branch, a lack of uniformity in the structure of the medullary rays is seen in the very weakly developed wood ring of the axis. At the base of the buds of the current year in which the immature wood cylinder has only the spiral ducts of the pith crown and a few libriform fibres, together with scattered, reticulated or porous ducts, medullary rays may be found here and there which vary from the other rays in the somewhat greater width of the cells, the somewhat stronger refractive power of the cell walls, the distinct straight course and the further continuation in the bark. It is noteworthy here that the end of the phloem ray extending furthermost into the bark, unlike the other phloem rays, is not more slender than those behind it, but broader, in fact, the broadest of all the cells composing the ray. While, therefore, the normal medullary rays are conical, this one has turned its broadest base toward the periphery. This is the same tendency in growth, found in the older stages, which appear as distinct excrescence rays. Such a differentiation in the earliest stage shows how this goitre gnarl formation *is prepared in the first juvenile phases of the axis.*

Besides the excrescences of the medullary rays, there are still other factors which distend the bark during the encysting of diseased tissue centres. We will return to these points in the section on the *"tuber gnarls"* which are best treated under the processes of wound healing.

I had an opportunity to observe in *Prunus Padus* the formation of goitre gnarls, which branch like witches broom, and have found similar structures on gooseberries[1]. I also found warty gnarls, similar to those described in Ribes, in *Cydonia vulgaris*[2]. On gooseberry bushes near compost heaps, I could later determine gnarl structures in a form similar to those in the black currant[3]. In a case in the red cherry currant, of which I heard only recently, long leafy shoots which had no mature buds on their leaf

[1] Jahresbericht des Sonderausschusses für Pflanzenschutz. Arb. d. Deutsch. Landw.-Ges. 1898, p. 145.
[2] Ibid. 1899, p. 188.
[3] Ibid. 1900, p. 218.

axes, developed from a goitre-like gnarl-knot. At the places where the pith bridge in the branch node otherwise leads to the bud, either no meristematic layer was found or it remained covered by a bark cap and developed into a small gnarl spike. Instead of the apical bud, I found accumulations of spike primordia which, in the following year, became actual goitre gnarls from which sprouted weak, leafy branches, as in Acer and Tilia.

So far as may be concluded from their description, the remarkable *"cylindrical gnarls"* (chichi, nipple) on *Gingko Biloba* may also be included under the goitre gnarls. According to Kenjiro Fujii[1] these chichi or nipples are found to be cylindrical or spherical excrescences which, as a rule, grow down perpendicularly from older branches. Their size varies from the length of a finger to 2 meters, with a thickness of 30 cm. They resemble normal branches, on which all foliage is lacking. Having reached the soil, they strike root and then are able to develop leaves. Similar formations are said to occur on the roots.

I have given a more thorough description to this form of the goitre gnarl formation, in which normal embryonic buds do not participate, because it demonstrates the ***importance*** of the ***medullary ray tissue*** in a way which, as yet, has not received the slightest consideration. Frank[2] cites references, deserving attention, and also describes earlier observations on gnarl structures. In this, however, the chief concern is the explanation of the wavy course of the wood fibres in gnarled wood. We lay the chief weight on the causes, which lead to the broadening of the medullary rays. The form of goitre gnarl, last described, is only the extreme of a tendency to an excrescence of the medullary rays, which may lead to certain canker swellings. In them, however, processes are involved which are caused by wounds, while here we can ascertain internal disturbances in the equilibrium of the processes of growth, but no external ones.

We are concerned with local increases of pressure and turgor conditions brought about by the form of nutrition. Kny's[3] investigations in this connection, give us the desired proof. He found, in the action of mechanical pressure, that, in the meristematic cells of the medullary rays, the division walls take a different direction and produce two-rowed medullary rays. In this instance, the results of mechanical pressure from outside. must, according to our conception of the matter, be affected also by the mutual pressure of the tissues upon one another, caused by increase in turgor. Since, however, turgor,—a sufficient water supply being presupposed,—depends on the constitution of the cell contents, on the abundant presence of compounds which attract water, each increased supply of plastic food material will give rise to an increase in turgor and a change of the existing pressure conditions in the different tissue forms.

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[1] Kenjiro Fujii, On the nature and origin of so-called "chichi" (nipple) of **Gingko biloba.** Bot. Magazine. Vol. IX, No. 105.

[2] Frank, A. B., Die Krankheiten der Pflanzen. 2d ed., Part 1, p. 82.

[3] Kny, L., Über den Einfluss von Druck und Zug usw. Pringsheims Jahrb. f. wiss. Bot. 1901. Vol. XXXVII, p. 55.

Such an increased supply of plastic food material is present, if some disturbance in the normal economy of the plant arises, due to the removal of certain centers of consumption. Goitre gnarl formation arises from the removal of branches necessitated by trimming the trunks and various other kinds of pruning. We find striking examples of this in lindens, poplars, maples, etc., planted along streets; in an ever-increasing accumulation of buds at the places where branches have been removed. If such gnarl accumuations occur at especially preferred places, well suited for the work of assimilation, some shoots from these gnarls gain the upperhand and approximate water sprouts.

c. Effect of an Excess of Nitrogen.

As seen already, a disturbance in the *formal* development of the plant body by a local accumulation of the prepared building materials is, to be sure, of interest scientifically but has no great disadvantage agriculturally. Indeed, we actually find that the cultivation of such formal variations, as doubled flowers, is often intentionally increased. The conditions are very different, however, if the *material* processes are unequally affected by the raw materials. Here the question of fertilization comes primarily under consideration and disturbances are especially involved which are produced by an excess of nitrogen and an unequal increase of the supply of potassium.

We have already mentioned the fact that the soil will be injuriously influenced physically by an over-abundant supply of soluble fertilizing salts. Even if the salts keep the soil damper, as long as sufficient atmospheric precipitation is present, yet they form a constant menace for the plants in time of drought, because a *too highly concentrated soil solution* may easily be produced, making more difficult the passage of the water into the plant roots[1]. This cannot fail to have some effect on the development of the plant. Gerneck's[2] work throws some light on this subject. He observed in Triticum that root hairs were formed more abundantly if $Ca(NO_3)_2$ was added than if KNO_3 was used. In feeding with nitrates, the blades and ears developed late, while, with chlorid and phosphate fertilization, they appeared early. With the latter method, the root cells appeared to be more thickened than with the former, in which the epidermal cells and the leaf schlerenchyma were also the least lignified.

We will now discuss a few special cases.

Over-Fertilized Seed.

The erroneous theory that plants can be brought to unbounded perfection by abundant fertilization has given rise to an endeavor to give seeds additional help by fertilizing them at the time of sowing. The seeds were either *"candied,"* i. e. coated with a crust of nutrients, or they were soaked

[1] Wollny, L., Untersuchungen über den Einfluss der Salze auf die Bodenfeuchtigkeit. Vierteljahrsschr. d. Bayer. Landwirtschaftsrates 1899. Supplement p. 437.

[2] Gerneck, R., Über die Bedeutung anorganischer Salze für die Entwicklung und den Bau der höheren Pflanzen. Göttinger Dissertation. cit. Just, Bot. Jahresber. 1902, II, p. 301.

in more or less concentrated nutrient solutions. The discovery was then made immediately, that such treatment assistance is often useless, and sometimes injurious.

Fertilization experiments with beets, made by Fremy and Déhérain, throw some light on this point. They proved that ammonium sulfate and potassium salts have an injurious effect on the germinative process, and they also found that germination failed entirely, even with a concentration of 0.2 per cent. The results of soaking experiments made by Tautphöus[1] with beans, peas, maize, rape, rye and wheat proved that seeds soaked in distilled water germinated best of all and that the capacity for germination was the more reduced, the more concentrated the solutions (potassium chlorid, sodium chlorid, (commercial) sodium nitrate, potassium sulfate, potassium phosphate and calcium nitrate in a solution of 0.5 to 5 per cent.). Rape germinated in a 2 per cent. solution almost as well as in distilled water, while the other seeds were considerably impaired, even in a 0.5 per cent. solution. The development of the seedlings was considerably more luxuriant in a 3 per cent. sodium chlorid solution than in distilled water.

Fleischer[2] reports on an experiment made in East Prussia, in fertilizing potato seed with kainit and superphosphates; a considerable number did not sprout and at the time of harvesting were found unchanged in the soil. The analysis of these tubers gave a content of pure ash nearly twice as great as the average values given in Wolff's ash analyses. In a thousand parts of dry weight the ungerminated tubers, compared with normal ones, contained potassium in the proportion of 37 to 22. While the calcium content was almost the same in the diseased and normal tubers, the magnesium was apparently twice as great in the former; the phosphoric acid almost double, and the chlorin content thirteen times as great as in the normal tubers. The sulfuric acid also increased to four times the amount in one thousand parts of dry weight, so that it is evident that exactly the elements of the kainit (potassium, sodium, magnesia, sulfuric acid and chlorin) had undergone an unusual increase in the ash of the unsprouted tubers. In the present case, the fertilizer was applied in the spring directly before the potatoes were planted, not sometime previous to planting, as prescribed in the directions for the use of kainit.

In Fittbogen's[3] field experiments with oats, which had been mixed in a gruel of superphosphate before sowing, the plot sown with *candied seed* yielded less than did that with unfertilized seed. If, on the other hand, the superphosphate was diluted with sawdust, the yield was the heaviest of all. Probably the sulfuric acid hydrate which often appears, together with phosphoric acid hydrate, also acts injuriously in direct contact with the superphosphate. Brügmann[4] also reports on the injurious action of fer-

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1 Tautphöus, v., Die Keimung der Samen bei verschiedener Beschaffenheit derselben. cit. Bot. Jahresber. 1876, II, p. 117.

2 Beobachtungen über den schädlichen Einflufs der Kainit- und Superphosphat-düngung auf die Keimfähigkeit der Kartoffeln. Biedermann's Centralbl. 1880, p. 765.

3 Deutsche landwirtschaftl. Presse 1877, No. 81.

4 Hannover'sche landwirtsch. Zeit. 1881, No. 12.

tiliers made soluble by sulfuric acid. This action was very evident in dry springs, and, in fact, on wheat as well as on other cultivated plants.

In seeds, the injurious effect of the "candying" will be the less felt the longer the seed lies in the soil, before sprouting, for then frequent rains can wash more of the fertilizing salt into the surrounding soil. This has been demonstrated in earlier experiments in Salzmünde[1].

Over-Fertilized Beets.

Common experience with present intensive beet cultivation, shows that an increased nitrogen supply increases the harvest in bulk, but reduces the sugar content. For this reason we will give only one proof that shows the importance of the form in which the nitrogen is applied. Pagnoul[2] analyzed three beets, of which the first (H) had been watered several times with a solution of (commercial) nitrate of soda; the second (J) with ammonium sulfate; while the third (K) represented a normal beet, harvested at the same time.

	H.	J.	K.
The harvest weight amounted to	4145g	2670g	785g
Density of the sap amounted to	1.026	1.040	1.046
Percentage of sugar in the beet substance amounted to	3.9	6.3	8.3
CO_2, and Chloral alkalies in 100 parts beet substance amounted to	1.991	0.924	0.814
The amount of these in 100 parts sugar is	28.0	14.6	9.8

It is evident that with nitrogen fertilization the amount of fresh substance harvested has increased three and a half to five times that obtained with normal cultivation, but the sugar percentage has fallen to one-half. The comparison of the effect of the nitric nitrogen with that of ammoniacal nitrogen is especially interesting. Mention was made above that the latter gives rise to a considerably greater ammonium content in the beet substance.

Müller-Thurgau's recent experiments[3] show that the nitrogen fertilized plants have a heightened respiration, which may well be the result of a heightened conversion of cane sugar into the directly reducing sugar. On an average every 6 beets contained

	Sugar, directly reducing,	Cane sugar
Beets rich in nitrogen	0.34 per cent.	8.27 per cent.
Beets poorer in nitrogen	0.04 per cent.	14.39 per cent.

An idea of the processes which are initiated by a superabundant nitrogen supply may be obtained from the statements of Pfeiffer-Wendessen[4],

1 Jahresber. f. Agrikulturchemie 1863, p. 60.
2 Annales agronomiques 1876, p. 321.
3 s. Überdüngte Kartoffeln. p. 390.
4 Bericht über die Generalversammlung d. landwirtschaftl. Centralver. f. d. Herzogtum Braunschweig. Blätter f. Zuckerrübenbau 1896, No. 8.

who is of the opinion that in any case the nitrogen is transformed into proteins, which, in combination with calcium, are decomposed into asparagin, glutamin and corresponding organic salts. These form soluble salts with calcium, which in turn are found again in the sugar extractives, etc. Schultze also characterizes the incompletely utilized, intermediary nitrogen compounds as essential constituents of the syrup which impair the crystallization of the sugar. In the plant itself, as in sugar manufacture, the compounds here named may retard the precipitation of the sugar, and thus explain the condition of *unripeness* and of small sugar content in the over-manured beets. Besides the delay in ripening, the beets do not keep well when stored in piles. Phosphoric acid improves the quality; the juice of beets, which had been over-fertilized with phosphoric acid and badly polarized, contained the fewest elements which prevent the crystallization of the sugar.

Good and bad experimental results have been obtained from *top dressing chiefly with Chile saltpetre.* This condition is observed in almost all experiments. Besides the quantity used, the result depends also on the way in which the plant utilizes the fertilizer. This differs greatly according to the variety, the density of the soil, the way it is worked, the locality and the weather. Reference should be made to Kuntze-Delitsch's[1] observations on top dressing. He found that the soil easily forms a crust, causing the young beets to die in spots because of a lack of oxygen, while the older ones develop poorly. In any case, fertilization with Chile saltpetre should be followed immediately by harrowing[2].

Opinions differ as to the advisability of using nitrogen fertilizers with seed beets. While it is asserted by some that the quality of the strain declines, Wilfarth[3], on the strength of his experiments, contradicts this statement.

Over-Fertilized Potatoes.

The effects of over-fertilizing potatoes with nitrogenous fertilizers are the same as for beets. Müller-Thurgau's[4] results show for both that an abundant nitrogen fertilization causes a stronger leaf development with a greater chlorophyll content. At the same time, the formation of starch is impeded; the starch is more rapidly dissolved in the leaves, and smaller quantities are stored. The organs show a greater glycose content, the reserve substances are more rapidly dissolved, the nitrogen compounds are more extensively transformed, while respiration is heightened and growth increased.

A poorer keeping quality of the tubers is correlative with a lesser supply of reserve substances and their more rapid consumption in respiration.

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[1] cit. Zeitschr. f. Pflanzenkrankh. 1896, p. 310.

[2] The action of the perchlorate in the use of Chile saltpetre will be discussed under the section on Injurious gases and liquids.

[3] Wilfarth, H., Wirkt eine Stickstoffdüngung der Samenrüben schädlich usw. Zeitschr. d. Ver. Deutsch. Zuckerindustrie. Vol. 50, Part 528, p. 59.

[4] Müller-Thurgau, Dritter Jahresbericht des pflanzenphysiol. Laboratoriums d. Versuchsstat. Wädensweil. Zürich 1894, p. 52.

But an excess of nitrogen directly promotes decay, while that of calcium phosphate has an opposite effect. I planted in sandy soil, in alternating rows, pieces of healthy tubers from three varieties as different as possible and also pieces from tubers suffering from *black dry rot*[1]. This field was divided into two halves absolutely similarly planted, of which one was given large amounts of Chile saltpetre on all the rows, the other Thomas slag. In the healthy seed, in the half fertilized with Chile saltpetre, the tubers sprouted very imperfectly while almost all the diseased seed had decayed. The results obtained in the plot fertilized with Thomas slag were directly opposite. There the diseased seed yielded very uniform healthy plants.

In the last named plot, plants from healthy and diseased seed of all varieties developed shorter shoots with more highly colored foliage. They ripened more rapidly and the harvest was nearly twice as large as from the plot fertilized with Chile saltpetre[2].

With this might be associated also the phenomenon well-known in practical circles as *iron spottedness* or the *multi-colored condition* of potatoes. Tubers outwardly normal have brown or brownish-gray places in their tissue in the fresh cross-section. In this, the rest of the flesh can be perfectly healthy and remain white, or, exposed to the air, may quickly assume a rusty red color. The spots originally discolored have brown, dead cell walls and many still contain starch. Often, and, in fact, when the cut surface subsequently turns red in the air, only traces of starch may be found in the diseased centres, but sugar is found instead.

While some observers think the iron spottedness must be traced to an abundance of acid iron compounds in the soil, others are inclined to believe dampness to be the cause. Many discoveries show, however, that heavy fertilization with stable manure caused the iron-spotted condition in certain varieties, which, in the same year, with chemical fertilization, remained healthy[3]. Tubers which turn red, when cut, are found most frequently where an abundant nitrogen fertilization is used. Hence one is justified in considering a multi-colored condition of the flesh to be an indication of nitrogen over-fertilization. Tubers with iron spots, as a rule, yield healthy plants in the following year.

Chile Saltpetre With Woody Plants.

Janorschke[4] has investigated the phenomena of nitrogen fertilization without the addition of calcium and phosphoric acid. He found that plants with multi-colored leaves became greener for the first year or two. In dwarf fruits the branches continued to grow almost without interruption until August and even later, which thus prevented the setting of the blossom buds. Attention should also be called to the fact that the effect of the fertilizer

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1 Zeitschr. f. Pflanzenkrankh. 1894, p. 126, und 1895, p. 98.
2 Zeitsch. d. Landwirtschaftskammer f. d. Prov. Schlesien 1899.
3 s. Jahresberichte des Sonderausschusses für Pflanzenschutz, herausgegeben v. d. Deutsch. Landw.-Ges.
4 Zeitschr. d. Landwirtschaftskammer f. Schlesien 1898, No. 34.

on trees does not make itself felt until the year following its application, but then has a continuous action up to the third year. From my own experiments, in which *sewage* was used, I consider the increased tendency of the fruit to decay, especially when it begins at the core, as well as the greater susceptibility to frost, to be the effect of a one-sided, excessive nitrogen fertilization. Calcium phosphate counteracts this evil. Experiments with apple trees, abundantly fertilized with saltpetre, showed that the fertilized trees suffered more from *aphids* than did unfertilized trees[1].

The foliage of *Ailanthus glandulosa* growing in well-fertilized positions became yellow and the branches blighted. On the cut surfaces of fresh branches Penicillium developed abundantly. The sugar content of the tissue at this place was very great.

In orange plantations, fertilized trees tended to gummosis and the disease called *"Die-back"* in Florida is traced directly to over-feeding with organic nitrogenous compounds. These orange trees are said also to be more susceptible to insect attacks[2].

Over-Fertilization of Vegetables and Other Field Crops.

Although our vegetables, as a whole, in their present form, are the product of a high degree of cultivation, and have adjusted themselves to abundant fertilization, we still often find cases of disease due to over-fertilization, especially where *sewage* has been used. There is a perceptible increase of the easily oxidizable substances which turn brown in the air. In this case, the walls of the ducts turn brown and, not infrequently, some of the ducts are filled with an inky fluid. Bacterial decay occurs frequently in over-fertilized plants. Peas and other Leguminoseae withstand least of all an excess of nitrogen while increased adaptation is found in some Umbelliferae, as *celery* for example. But even here the favorable amount is often exceeded in sewage bed cultivation. If the cut surface of fleshy root tubers becomes rusty, the tubers as a rule have lost in flavor. The more advanced stage, frequently found in vegetables shown in the markets of large cities, consists of an increased sponginess of the tissue and a greater brown spottedness. Such conditions and the bacterial decay, connected with them, manifest themselves in cabbage plants accustomed to nutrient solutions of the highest concentration. Under such conditions it is advisable to add calcium phosphate and to cultivate continuously.

Owing to the increased use of rhubarb stalks as a spring sauce, the plants are being cultivated on sewage beds. In such plantations I observed cases where the unusually thick stems were absolutely insipid. Thus a scanty production, or a complete consumption of the organic acids, is connected with over-fertilization. In my opinion this *regression in the amount*

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1 Fünfter Jahresber. d. Grofsherzogl. Obstbauschule zu Friedberg i. d. W.

2 Webber, H., Fertilization of the soil, etc. Yearbook U. S. Depart. Agric. for 1894. Washington 1895, p. 193.

of acid associated with an excess of nitrogen may also be sought elsewhere and may be the cause of the rapid appearance of bacterial decay[1].

In the Cucurbitaceae (cucumbers and melons) a concentration of the nutrient solution, not dangerous in itself, can act injuriously if the temperature is continuously too low. In this case gum appears most abundantly on the fruit and connected with it a blackening of the ducts is also noticed.

In tobacco culture, an excess of nitrogen manifests itself in coarser leaves and a larger nicotine content[2].

Mention has been made of the fact that sewage fertilization of grain may cause lodging and sterility.

EXCESSIVE NITROGEN FERTILIZATION FOR DECORATIVE PLANTS.

Very numerous cases of this may be found. Besides fertilization with sewage and Chile saltpetre, or ammonium sulfate, *horn shavings* are extensively used, especially for garden plants. Naturally we can cite only a few examples. I gave a few plants of *Begonia semperflorens* an excess of ammonium sulfate. Four days after fertilization the young shoots became discolored at the base and began to drop. The edges of the leaves began to show dirty green areas which later became brown and dried up. These were connected with the healthy tissue at the centre of the leaf by a more transparent transitional zone. In the sun, the wilting became more rapid. The pith and bark were found to be filled with masses of calcium oxalate; the individual crystals were not as sharp as those in healthy specimens but more rounded like tubers. No starch was present in the diseased tissues and the chloroplastids were reduced to small angular grains. The ducts were frequently filled with a brown, granular content. The cell walls of all the tissues were brown. The contents of the epidermal cells of the leaves were brown and granular. Before the decomposition of the chlorophyll grains, brown drops were often found in the contents of the mesophyll cells.

In Begonias, as well as in *Pelargonium zonale,* the leaves discolor and fall off easily when dried. I found an unusual number of calcium oxalate crystals in the pith and young bark of the axes of diseased plants. The stems of the Pelargoniums contained in general fewer and smaller starch grains. They were almost entirely lacking in the bark parenchyma, while, in the over-fertilized plants, they were present in abundance.

This is an example of the same phenomenon observed in potatoes and beets,—i. e., a poverty in carbohydrates.

A slight fertilization with Chile saltpetre, given to freshly rooted Pelargonium cuttings at first caused a very luxuriant growth. Later, because of frequent repetition, the effects became serious;—the leaves drooped, and brown decayed areas appeared on the stem just above the leaf bud. In a a short time these spots encircled the entire stem. Then the leaves fell and

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1 See Action of oxalic acid, p. 361.

2 Schellmann, W., Der Tabak und seine Nahrungsansprüche. "Der Pflanzer." Herausg. Usambara-Post 1905, No. 5.

the whole aërial axis died back to a short stump. New, weak shoots then began to sprout. We have cited this example, in order to show that the effect of over-fertilization, although it takes place through the soil, does not make itself felt at first at the base of the axes but on the peripheral organs, the leaves.

In comparative experiments with Fuchsia cuttings[1], a *continued* fertilization with small amounts of ammonium sulfate resulted in a noticeable increase in growth and an enlargement of the leaves. The epidermal cells of the leaves had thinner walls and the wood ring of the branches made a weaker development. The starch content was smaller, the chlorophyll content larger, the period of growth lengthened. When the fuchsias were protected from autumnal frosts, by being brought into a greenhouse, they had time to ripen normally, and the differences as compared with unfertilized plants disappeared. The fertilized ones had rather the advantage in a greater growth. Here we have a result such as is evident in growing fodder beets. The addition of large amounts of nitrogen *retards the ripening process.* If the plants can reach maturity before frost, so that the leaves ripen normally, we obtain the desired results from fertilization, i. e., the production of greater amounts of material, with a normal supply of reserve substances. But, as a rule, the climatic conditions prevent the termination of growth and winter finds the organs in an immature condition.

The disadvantage of harvesting insufficiently matured plants has been emphasized under "agricultural crops." Such plants have a greater tendency to decay.

The same results were obtained with comparative fertilization experiments with Erica. The red blossoming varieties developed less vividly red or almost bluish red blossoms in the series of experiments with a one-sided nitrogen fertilization; their habit of growth was more drooping and the blossoms set less abundantly. The fertilized specimens suffered so greatly from *Botrytis cinerea* in winter that most of them died, while unfertilized plants of the same varieties from the same place came through the winter uninjured. Bluth[2] carried out an experiment which showed the effect of a highly concentrated solution of all the nutrient substances. The Ericas, in the second year of cultivation, were given continued supplies of a one-tenth per cent. solution of Wagner's nutrient salt. After ten to twelve days the leaves became a darker color and their growth stronger, but the plants showed a *greater sensitiveness to the action of the sun and drought,* in comparison with many hundreds of unfertilized specimens of the same variety. The new lateral shoots of certain tender varieties (*E. hiemalis, E. congesta,* etc.) developed a drooping and often curved habit of growth. Hard needled varieties (*E. blanda, E. mediterranea, E. verticillata, E. mammosa*) retained their erect habit of growth but *the buds set* in a strikingly small

[1] Sorauer, P., Einfluss einseitiger Stickstoffdüngung. Zeitschr. f. Pflanzenkrankheiten 1897, p. 287.

[2] Zeitschr. f. Pflanzenkrankh. 1895, p. 186.

number, or not at all, while the branches continued growth. Here too, for the most part, the fertilized plants died during the winter from Botrytis. In other fertilization experiments, made with horn shavings on Ericas, there was *a luxuriant leaf development at the expense of the blossom buds,* but the fertilized plants, during the winter, showed no greater weakness.

From the many instances which have come to my notice, I must state the frequent *"failure of forced Lilies-of-the-Valley,"* as due to an excessive nitrogen fertilization. Chile saltpetre and ammonium sulfate are often used when the plants are grown for two years out of doors.

The plants grow more luxuriantly and their very strong (mostly blue-tipped) *"pips"* (bud-cones) deceive the buyer; the formation of the inflorescences, however, is weak. Such plants force with great difficulty and frequently bear flower clusters in which some buds do not mature. Comparative experiments made by Koopmann[1] showed very interesting differences in forcing. When kainit was used as a fertilizer in growing the plants, the flower clusters developed first and the leaves followed very slowly,—on the other hand, when ammonia was used the leaf growth was so luxuriant that the flower clusters were entirely hidden by the leaves. In general, potassium may be recommended as a fertilizer for Lilies-of-the-Valley.

A further injurious effect could be determined *for Roses.* I have before me observations showing that tea roses, among others, *Maréchal Niel* and Nyphetos, grown indoors, drop their buds after heavy fertilization, or decay at the point where the calyx passes over into the stem. When diseased plants had been repotted in a sandy soil poor in nutrients, normal blossoms developed in the following year. I observed similar phenomena of decay in Bourbon and Remontant roses in the open after sewage fertilization. Here, an application of gypsum gradually decreased the disease.

In other garden plants, even in ivy, I had opportunity to observe phenomena of decay after an excess of nitrogen (usually in the form of sewage fertilizers, liquid manure, Chile saltpetre and ammonium sulfate). In the majority of cases, I have recommended transplanting the plants into pure *sand* or a very sandy leaf loam for a year and have tried it myself repeatedly with good results.

Leaf Curl of the Potato.

We will include here this disease so well-known to potato growers and so often studied scientifically; the causes of which, however, are still unknown. The reason for considering leaf curl here is the deduction from my observations that diseased shoots show characteristic evidences of one-sided nitrogen fertilization. Direct results are not involved here, only the after effects in the following year. The parent tuber is either immature in a few eyes, or entirely so. In the following year a diseased condition develops in all of the shoots or only in *some* of them. This limitation of the

[1] Zeitschr. f. Pflanzenkrankh. 1894, p. 314.

attack is to be emphasized, because, at times, up to the present, observers have emphasized especially that *all* the stems on a tuber become diseased, i. e. that the cause of the disease must lie in the whole tuber, while my observations have shown beyond question that the diseased condition may be limited to a few eyes.

According to Kühn[1], the disease appeared as an epidemic first in 1770 in England and in 1776 in Germany, causing extraordinary losses. The first symptom is the discoloration of the leaves which no longer have the fresh appearance of healthy plants. The main leaf stem is usually found bent downward or completely rolled up; the various leaflets are folded, curled here and there and covered with brown, usually longish spots. The latter extend as far as the main rib of the leaf and finally to the stem. At first only the superficial cells are brown, later the disease extends deeper into the tissue, even to the pith of the stem. This changes the consistency of the stem from a normal flexibility to a glassy brittleness. In addition, according to Schacht, sugar is found very abundantly in the diseased cells[2]. If such plants live until harvest time, they either set no tubers at all or only a very few.

In the earlier literature, very different causes (including parasitic fungi) are given, as shown by reference to the previous edition of this manual. Newer theories may be found in Frank's[3] study. He distinguishes a number of different forms of the disease and, agreeing with me, states that the very beginnings of the diseased condition do not show any fungous action. The cause of the death of the protoplasm in the various brown tissue centers is not known. Differing from my observations, however, Frank emphasizes "that all the shoots of a plant became sick simultaneously[4]."

In making more extensive cultural experiments, using several varieties, and directed especially to the study of leaf curl, I found that the phenomena of disease appeared initially only in one variety (*Early Puritan*). The diseased plants, scattered among the healthy ones, made only a third as much growth and showed the well-known characteristics, especially the breaking of the curled leaves. Small corky fissures were often found on the petioles. The first stages of the disease on the stems were found in one of the internodes below the surface of the soil, where a blackening of the duct walls could be determined. This characteristic can be traced back, radiating more or less deeply into the tuber which otherwise seems healthy. This shows that the tuber has not carried the disease to the shoot but, conversely. In the same way, the browning of the ducts radiates out from the diseased

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[1] Kühn, Jul., Krankheiten d. Kulturgewächse. 1858, p. 200. — Ber. aus. d. physiolog. Laborat. d. landwirtsch. Instituts zu Halle. 1872, Part I, p. 90.

[2] Bericht an das Kgl. Landesökonomiekollegium über die Kartoffelpflanze und und deren Krankheiten. 1854, p. 11.

[3] Frank, A. B., Die pilzparasitären Krankheiten der Pflanzen. Breslau 1896, p. 300. — Kampfbuch gegen die Schädlinge unserer Feldfrüchte. Berlin, Parey, 1897, p. 217.

[4] Kampfbuch p. 222.

stem node into the roots, produced at that point, and may be found in the whole part of the axis which is still green, up to the ribs of the last leaves.

Especially striking is the sap turgescence in the apparently perfectly healthy parent tuber which exhibits some cells with large unconsumed starch grains. The groups of cells containing the starch lie scattered in the very turgescent parenchyma of the tubers, which shows scarcely any traces of solid cell contents, while the nuclei are large.

It is further noteworthy that, just as healthy and diseased shoots may be produced from one tuber, the characteristics of disease on the same stem can often be restricted to definite areas. Healthy eyes may develop on diseased stems and diseased stems are found in which only half of the vascular bundle ring is blackened.

Thus, like other diseases connected with the discoloration of the ducts, leaf curl begins to manifest the first symptoms of disease at the periphery. The cuticle blackens most of all. The cell contents began to change color at first to a weak inky color, until the walls and contents have become uniformly brown, after which the epidermal cell collapses.

Where the epidermis borders on the collenchymatous tissue, the discoloration advances in its walls. They become slightly yellowish at first, then reddish yellow (in some varieties a peculiar blood red), and finally brown. This discoloration of the walls, which seems to spread rapidly tangentially, recalls enzymatic activities.

The further course of the disease differs in the different varieties, probably because the cell walls vary in construction, some being more loosely built, others more solidly. In *Early Puritan* it was observed that the browned cell walls could be attacked by a granular decay, in which small rod-like bacteria probably participated. In these cases the tissue disappeared, while holes and depressions appeared in the bark tissue of the stem and mycelium was found. In *Early Puritan* the depressions deepened to the wood ring and, as the disease advanced, their pressure could be demonstrated even on the still green tips of the stems. The browning of the ducts, however, did not proceed from them; it began at the base of the stem and spread only in the vascular system. At the torn places processes of healing often manifested themselves in the pouch-like elongation of the adjacent, healthy bark parenchyma cells.

The statement given above, that the symptoms of disease do not universally appear uniformly relates, for example, to the appearance of ***brown specks*** on the uncurled leaves. However, in the petioles of these leaves there is exactly the same pale inky filling of the ducts which, in some cases, thickens to a grainy slime; the walls of the ducts also are browned.

The characteristics here described occur separately also in other plants with an excess of nitrogen. If these symptoms are compared with the results of earlier observations, leaf curl may be described as follows. The diseased condition appears most luxuriantly and abundantly on tender early varieties. The harvested tubers are immature, being distinguished by a

smoother skin, a lower starch content and a considerably higher potassium content. They are also smaller in size and have a smaller dry weight. Under favorable conditions, healthy plants may often be grown from such tubers.

Among the characteristics given, we have emphasized the length of the existence of the parent tuber, which remains turgid and retains starch, because Hiltner[1] has recently described such a case belonging here and, in fact, a partial *subsequent enlargement of the parent tuber.* Different people have made the same observations. In Hiltner's case it was also observed that the plants produced from the turgid tuber developed no tubers below the soil, attached to the stolens, but bore them directly on the lower internodes of the green stems. These stems, however, were only half as long as in normal plants and bore leaves, rolled together, which reminded Hiltner of leaf curl. He thinks that these processes are a result of the use of immature tubers for seed. These tubers, after developing the stem, had utilized in their own further growth the material obtained by the action of the leaves. Naturally too little organic substance remains for the tubers of the current year.

If we accept Hiltner's theory as to the production of tubers which remain turgid, we can infer that leaf curl results from the use of unsuitable seed. *The tubers were not sufficiently matured in the previous year.* This must also make itself felt in the full development of the individual eyes. While the majority of these had time to develop normally, some may have remained immature and have retained this character when sprouting in the following year. This will explain the fact that often only isolated shoots are found which show leaf curl. The characteristic of immaturity is the marked abundance of potassium and nitrogen compounds with a scanty deposition of carbohydrates as reserve substances. We find such conditions favored by the use of fresh manure with early varieties and drought stops the growth of the tubers prematurely.

If an over-supply of nitrogenous compounds, not normally utilized, determines the appearance of leaf curl in the potato, the shrivelling disease of the mulberry tree, and other diseases, to be mentioned under "Enzymatic Diseases," then the symptoms of the blackening of the ducts and rapid bacterial infection, already found, may be explained easily.

This theory is further supported by a study made by Appel[2], who, under the name *"Bacterial-ring disease,"* describes the phenomena which often suggest leaf curl. He makes bacteria responsible for the ring disease and "indeed, as in black-leg, not one species alone but a few closely related forms." "These bacteria are undoubtedly present normally in many soils. . . . ." Influenced by these statements I should like to include bacterial ring disease under those diseases in which a constitutional weakness in the plant and not a parasite determines the phenomenon and favors

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[1] Hiltner, L., Zur Frage des Abbaues der Kartoffeln. Prakt. Bl. f. Pflanzenbau und Pflanzenschutz 1905, Part 12.

[2] Appel, O., Die Bakterien-Ringkrankheit der Kartoffel. Flugblatt 36 d. Kais. Biolog. Anst. Dahlem. 1906.

especially the spread of the bacterial infection. These conditions are similar to those described as leaf curl, in which I likewise have observed decomposition of the tissue by bacteria.

It thus seems that we have before us a whole group of potato diseases, with the common characteristic that the ducts turn black. This may be traced to the fact that incompletely consumed nitrogenous compounds make their influence felt in an insufficient development of the carbohydrates.

We must seek to overcome this condition to the best of our ability by fulfilling the requirements for a gradual, complete ripening of the tubers on the plant.

d. Excess of Calcium and Magnesium.

In addition to the observations on the use of lime as mentioned in earlier sections, we will emphasize here first of all Orth's[1] warning that it should be supplied to the field in small, frequent doses rather than in one heavy application.

Of course, an *excess of calcium* cannot be determined exactly by definite figures, since the demand of each plant and each field is different. Also, in adding the lime it does not depend at all on the absolute amount of calcium supplied but on the proportion to the other nutrients of which the calcium influences the solubility and capacity for transportation. Finally, the weather conditions at the time the lime is applied must be considered.

Hoffmann[2], from his broad experience, has given many warnings which are of utmost value practically. Calcium is injurious when used in large amounts on exhausted soils. On lighter, active soils, poor in humus, during dry springs, it loosens and dries the soil too much and disturbs the bacterial action. If it is used in the form of marl, it must first be well decomposed in the air, in order that possible injurious elements can be oxidized at the right time. Calcium acts detrimentally in continued drought, and also with stagnant water if it, in the form of so-called "water-lime," is mixed with a good amount of silicic acid, ferric oxide and clay. In wet weather, it becomes as hard as cement.

But even under normal conditions, calcium may be detrimental. We must not forget that, together with the desired effect of decomposing organic substances, containing nitrogen, and of transforming the ammonia produced into calcium nitrate, ammoniacal compounds are set free. If ammonium nitrate or ammonium sulfate is mixed with calcium carbonate or phosphate, it produces the very soluble calcium chlorid and gypsum and ammonium carbonate or phosphate. In Wagner's[3] experiments (Darmstadt), the loss of nitrogen, produced by the volitalization of ammonia, was observed to be 30 per cent. of that in a fertilization with nitrate. The same losses are produced very easily, if the soil is rich in calcium carbonate, if the ammonium

[1] Orth, A.. Kalk- und Mergeldüngung. Anleitung, im Auftrage d. Deutsch. Landw.-Ges. Berlin 1896.
[2] Hoffmann, M., Düngungsversuche mit Kalk. Arb. d. D. Landw.-Ges. Part 106.
[3] Zeitschr. der Landwirtschaftskammer f. d. Prov. Schlesien. 1904, p. 1683.

salt is only superficially worked in so that the sun and wind have abundant access to it. Then the free ammonium carbonate, produced by the transformation of the fixed ammonium sulfate, can be removed from the field very quickly.

Sandy soils, which at the time are rich in calcium, are on this account not suited for an ammonia fertilization, especially not as a top dressing. This explains why quick lime should not be brought directly into contact with stable manure or other ammonium fertilizers.

Besides these reactions, lime also acts on phosphoric acid. This action must not be underestimated. The action of the phosphoric acid on superphosphate, which is soluble in water, is impaired by the simultaneous use

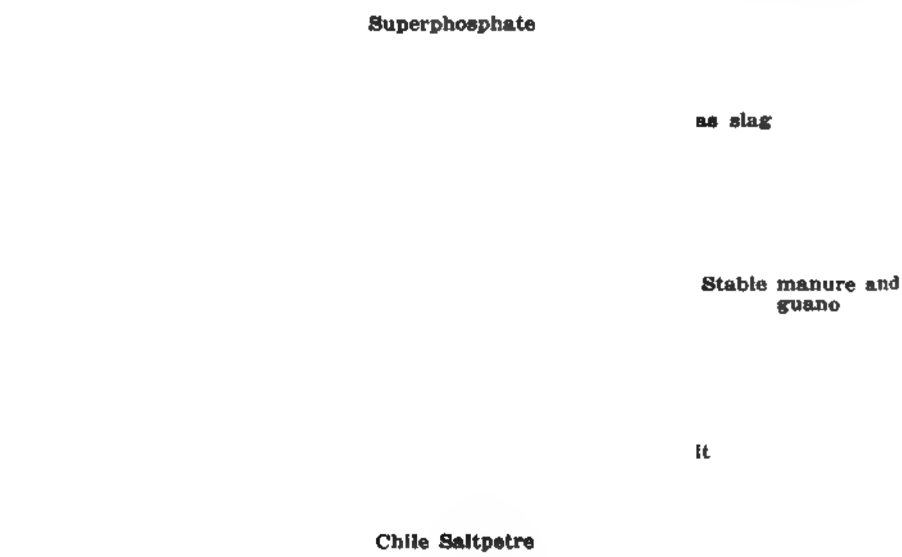

Fig. 66. Diagrammatic representation of the favorable and unfavorable mutual relations of fertilizers to each other.

of lime; but not so much so as the phosphoric acid in Thomas slag, soluble in citric acid. The destructive effect of lime on phosphoric acid is greatest when used with ground bone.

It may be the place here to refer to the mutual relation of fertilizers in order to avoid using them in such a way as to impair their action. Instead of more lengthy descriptions we will reprint a figure borrowed from the "Practical Advisor in Fruit and Garden Culture," 1906, No. 17[1].

In this diagram, the thin connecting lines signify that the various kinds of fertilizers may always be mixed together. The fertilizers, which appear connected by double lines, may be mixed with one another only very shortly before spreading; while those fertilizers connected in the figure with thick lines may *never* be mixed together.

1 "Praktischen Ratgeber im Obst- und Gartenbau." No. 17, 1906.

The poisonous effects of an *excess of magnesium* and the associated theory given by Loew, as to a definite quantitative relation between calcium and magnesium in the soil for obtaining good harvests, have been considered already in the section on "Lack of Calcium" (p. 301). Recently Loew[1] has supplemented his earlier statements by calling attention to the fact that the favorable quantitative relation between calcium and magnesium in the soil cannot always be fixed by definite figures. It changes as soon as the two bases are made accessible in different degrees for absorption by the plant.

Loew's theory is contradicted by experiments made by Meyer[2]. The emphatic fact here is that heavy additions of calcium as well as of magnesium can greatly impair the yield. Naturally the various plant species behave very differently with the same fertilizer. Given the same quantity of magnesium, the grain and straw yield of oats was lessened, but that of rye was not decreased.

Gôssel[3], on the basis of his own experiments, also considers Loew's point of view to be incorrect, yet we think it, nevertheless, worth consideration. Too much faith must not be put in definite figures because each cultural experiment offers different conditions. A constant effort must be made to overcome the injurious effects of the magnesium compounds whenever brought into the soil in great quantities in the fertilizer. Of first importance is the great quantity of magnesium chlorid spread on the field with the so-called *"waste salts"* which reduces the sugar content of beets, the starch content of potatoes, etc. An effort must be made to combine the non-absorbable chlorine with a base, especially calcium, so that it can be washed easily into the subsoil.

Finally attention must be called to the fact that the same amount of calcium acts injuriously at one time and beneficially at another, according to whether it is added in the forms of calcium carbonate or calcium sulfate. Thus, for example, Suzuki[4], found in vegetative experiments with mountain rice, that the yield was considerably reduced by an excessive addition of calcium carbonate (the proportion of calcium to magnesium was as 3:1), even if phosphoric acid was present in an easily soluble form. On the other hand the addition of an equivalent amount of *gypsum* caused an unusual increase in the yield, especially of grain. From this experiment, however, it is evident that the injurious action of an excess of calcium is not always to be sought in a decrease in the looseness of the soil as compared with that found after the use of slightly soluble phosphoric compounds, but probably has its foundation also in the neutralization of the root acids.

[1] Loew, O., and Aso, K., Über verschiedene Grade der Aufnahmefähigkeit von Pflanzennährstoffen durch die Pflanzen. Bull. College of Agric. Tokyo. Imp. Univ. Vol. VI. No. 4, cit. Centralbl. f. Agrik.-Chemie 1905, p. 594.

[2] Meyer, D., Untersuchungen über die Wirkung verschiedener Kalk- und Magnesiaformen. Landw. Jahrbücher Vol. XXXIII, 1904, p. 371.

[3] Gössel, Fr., Bedeutung der Kalk- und Magnesiasalze für die Pflanzenernährung. Vortrag auf d. 75. Naturf. Vers. (s. Chemikerz. 1903, No. 78).

[4] Suzuki, S., Über die schädliche Wirkung einer zu starken Kalkung des Bodens. Bull. College of Agric. Tokyo, Imp. University. Vol. VI. cit. Centralbl. f. Agrik.-Chem. 1905, p. 588.

By neutralizing the acids of the plant roots the available phosphoric acid will not be so largely absorbed. The great difference between the action of calcium carbonate and that of gypsum is due to the fact that gypsum is taken up from the soil only so far as it is soluble in water (i. e. in the very slightest amounts), while the absorption of the carbonate by the plant depends upon the carbonic acid of the root.

Excess of Calcium With Grapes.

Since the introduction of grapes grown on budded American vines there have been very many complaints of *Jaundice*. The disease is described usually as "*Chlorosis*"; but according to my conception it must be called "*Icterus.*"

Of course, the causes of the yellow condition of the foliage of grapes may differ very greatly, as in other plants. Very frequently, root decay, occurring with or without fungi, plays a rôle in heavy soils. *Vitis Riparia* and *V. rupestris,* with their weaker root systems are especially sensitive to such soils, while varieties with strong roots (Jacquez, Herbemont, etc.), better adapt themselves[1]. American vines, however, are grown with great difficulty on soils containing a great deal of calcium in an easily soluble form and not rich in nutrients. In France it was possible to collect the greatest amount of information on this subject. Luedecke[2] repeats the results of soil investigations which the agricultural society of Cadillac undertook in 1890. The soil which showed *no jaundice* of the vines and that which showed *jaundice* contained

	No jaundice	*jaundice*
Phosphoric acid	0.07 per cent.	0.06 per cent.
Potassium	0.39 per cent.	0.37 per cent.
Calcium	1.81 per cent.	18.93 per cent.
Ferric oxid	5.90 per cent.	3.02 per cent.
Nitrogen	0.10 per cent.	0.10 per cent.

The content of both soils in nitrogen, potassium and phosphoric acid, therefore, is about equal; the ferric oxid percentage is high in both, but the calcium is nearly ten times as great in the soil producing jaundice. In the fertilization experiments undertaken with Chile saltpetre, ammonia, superphosphate, potassium chlorid, magnesium sulfate and *iron sulfate* (ferric sulfate), only the last gave any satisfactory results. In this experimental plot, the vines formed a great many new roots. The same results were again obtained under similar conditions on soils naturally rich in iron, in which, therefore, the favorable action of fertilization with iron sulfate cannot be ascribed to a previous lack of iron.

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1 Eger, E., Untersuchungen über die Methoden der Schädlingsbekämpfung usw. Berlin, Paul Parey, 1905.

2 Luedecke in Zeitschr. f. d. landw. Ver. d. Grossherz. Hessen 1892, No. 41, 1893, No. 2.

Such results, proving that jaundice of the grape is due to a high calcium content are found[1] frequently as are also observations as to the effectiveness of the iron sulfate.

The question now is, how to explain the injurious effects of calcium and the beneficial action of the so-called iron compounds. Luedecke found that the water coming from the lime soils of Rhenish Hessen has an alkaline reaction, and he found that with an addition of some iron salt (iron sulfate or ferric chlorid), the iron was precipitated. He, therefore, came to the conclusion that, since plants are able to take up iron only in a dissolved form, and since the alkaline water prevents its solution, the grape vines suffer from a lack of iron in spite of the great amount of it in the soil; they, therefore, become icteric. Viala and Ravaz noticed the injurious action of lime in a neutralization of the cell sap of the roots[2].

Until we have the results of further experiments, we must be satisfied with the fact that large amounts of *easily soluble* calcium compounds will produce icterus of the grape, and that abundant additions of iron sulfate have often been found to be useful in combatting it. It is now of the first importance to consider that the affinity of the sulfuric acid of the iron compound for calcium is great and forms gypsum which, only slightly soluble, is proved to be non-injurious, or even beneficial to growth.

Eger[3] cites Oberlein-Beblenheim's experimental results, showing that, on rich soils, fertilization with gypsum considerably increases the yield. Since the addition of gypsum, made at the same time to poor soils, remains absolutely without result, the favorable action of the gypsum may probably be ascribed to its power of loosening up the soil.

e. Excess of Potassium.

Reference has been made already to the danger to soil constitution of a continued heavy potassium fertilization, and in this it was emphasized that lighter soils and moor soils responded more favorably to the addition of potassium. Recently, however, Hollrung has called attention to another disadvantage of all fertilization with mineral salts,—therefore, of potassium salts also. He refers to Hall's experiments, showing an absolute change in the water conditions in the soils. Hall determined (after 1866) the number of days in one year in which drainage flowed from an unfertilized field, as contrasted with one constantly fertilized with Chile saltpetre. The longer the drainage flows, the more water is removed from the field. Although the results fluctuated in the several periods of five years each, which he compared, yet as a whole for the entire length of time, they indicated that in the "salted soils," larger amounts of water had passed into the drainage through the subsoil. This makes possible conclusions as to an unfavorable transformation of the soil.

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[1] See v. Babo and Mach, Handbuch des Weinbaues and der Kellerwirtschaft (s. Eger).

[2] See Eger.

[3] Loc. cit. p. 84.

The effect of potassium salts on the plant depends on the form of the fertilizing salt and the soil on which it is used[1]. The question arises here as to the part played by the accessory salts incorporated in the soil with the addition of potassium. At present, *kainit* and the 40 per cent. potassium salt are used more extensively. With kainit, 3¼ cwt. should be used if one desires to add as much potassium as is present in one cwt. of 40 per cent. potassium salt. Among the accessory salts introduced in the kainit, sodium chlorid plays a prominent rôle. Besides this, magnesium sulfate and magnesium chlorid come under consideration. The individual plants behave very differently with sodium chlorid. Its effect on sugar beets is very good, but potatoes are very sensitive to it[2]. The results with sugar beets, however, are rather deceptive. According to Aducco and Wohltmann's experiments, the amount of beet substance harvested is increased, but the quotient of purity and the sugar content are reduced.

On account of the accessory salts, Schneidewind and Ringleben[3] tested raw potassium salts with different potassium compounds as contrasted with the highly concentrated forms. It was shown for a mixture of clover and grass, and for oats, sugar beets and potatoes, that kainit was superior to potassium chlorid and potassium sulfate, if sufficient amounts of calcium carbonate were present. If these were lacking, opposite results were obtained. If the slightly soluble gypsum was used, instead of calcium carbonate, kainit proved to be especially injurious for the mixture of clover and grass, but less so for oats. In potatoes the action was favorable if the soils were poor in potassium. With an increase of potassium, the effect of excess became evident, i. e. the starch content was lowered. Szollema[4] found that the decrease of starch, effected by the chlorid, which is connected with a greater abundance of water, was somewhat greater in the varieties of potatoes naturally rich in starch than in those poor in starch.

When plants are very sensitive to the chlorine compounds of the raw potassium salts, as, for example, kainit, the loss of potassium by its partial leaching from the soil during the autumn and winter, is really an advantage in so far as many of the dangerous accessory salts (sodium chlorid and magnesium chlorid), are washed out at the same time; therefore, while actually less potassium remains in the soil, it becomes more effective, because it is in a purer form. This leaching of the potassium must be taken into consideration in soils with only small amounts of calcium and other such absorbents, as, for example, in light, sandy, and moor soils[5].

Concerning the disadvantageous effects of potassium fertilization on cultivated plants, other than those already named, we will mention further

1 Blätter für Zuckerrübenbau 1905, p. 62.
2 Blätter für Zuckerrübenbau 1905, p. 89.
3 Schneidewind, W., and Ringleben, O., Die Wirkung der Kalirohstoffe und der reinen Kalisalze bei verschiedenen Kalkformen. Landwirtsch. Jahrib. 1904. Vol. XXXIII, p. 353.
4 Szollema, D., Über den Einfluss von Chlor- und anderen in den Stassfurter Rohsalzen vorkommenden Verbindungen etc. cit. Centralbl. f. Agrikultur-Chemie 1901, p. 516.
5 Schneidewind, Auswaschen des Kalis im Winter. Zeitschr. d. Landwirtschaftskammer f. Schlesien 1904, No. 14, p. 471.

the effect on *Tobacco* observed by Behrens[1]. His experiments showed that the water content of the leaves increased considerably if potassium sulfate was added to stable manure and that this hastened greatly the decay of the leaves which dry with difficulty in the air. This probably is connected with the increase in turgor observed by Copeland, which is due to potassium salts (Potash). Sodium salts (soda) did not show this physiological reaction[2].

The complaint of farmers that continued potassium fertilization reduces *the quality of pasture plants* so that animals fed with such hay, grow thin, should be considered here. Even if the statement that this excessive action occurs is still contestible, nevertheless it is true, that a decrease in flavor has been observed in the hay from fields repeatedly fertilized with kainit, or with kainit and Thomas slag[3].

The injuries appearing in different field crops and fruit trees are generally the result of an unexpedient use of potassium salts, a practice often followed by serious injury[4]. These will best be prevented by not using potassium in large amounts on heavy soils, by not spreading the salt with the seed, by repeated, smaller applications of potassium and (in plants especially sensitive to chlorine, as, for example, potatoes) by the use of the 40 per cent. potassium salt, and of other purified, highly concentrated compounds, instead of the commercial salts.

The frequent use of potassium in small quantities is often beneficial because the calcium in the soil water, containing carbon dioxid, will be more easily leached out the more potassium salts are added to the soil, since the calcium is converted by them into soluble compounds. Hoffman[5] recommends the use of a high per cent. commercial marl, where possible, and its application in at least 5 to 7½ double centner[6] per acre. If the soil is liable to become encrusted (*"be baked"*), at least 2½ double centner of quick lime should be turned under superficially in the autumn and repeated possibly four years later.

f. Excess of Phosphoric Acid.

Injuries due to an excess of phosphoric acid are rare. They can only be expected where superphosphates are used abundantly, i. e. where some phosphoric acid, soluble in water, is present. The phosphoric acid of Thomas slag, soluble in citric acid, is less mobile. However, even the phosphoric acid, soluble in water, passes over immediately into an insoluble form since the di-phosphates of calcium, magnesium, aluminum and iron formed in the soil, are dissolved only very slowly by the carbon dioxid of

1 Behrens, J., Weitere Beiträge zur Kenntnis der Tabakspflanze. Landw. Versuchsstationen 1899, p. 214.
2 Bot. Jahresber. 1897, I, p. 72.
3 Mitteilungen d. Deutsch. Landw.-Ges. vom 11. März 1905.
4 Clausen, Resultate von Obstbaumdüngungen. Landwirtschaftl. Jahrbücher Vol. XXXIII, p. 939.
5 Hoffmann, M., Die Kalisalze. Anleitung. Herausg. v. d. Deutsch. Landw. Gesellsch. 3d ed., 1905.
6 A double centner equals 220 lbs.

the soil and the acid secretions of the roots. Injury from superphosphates is, therefore, to be feared even with heavy applications only on soils which are poor in calcium, iron and aluminum carbonates. There are only a small number of experiments on this subject. The careful investigations, made at the experimental station in Bernburg, on sugar beets[1] fertilized with the monobasic calcium phosphate, i. e., excess of phosphoric acid soluble in water, have shown that the sugar content does not decrease and also that the amounts of beet substance and non-sugar have remained the same as in normally fertilized beets.

So far as my own experience goes, an excess of phosphoric acid may manifest itself in a shortening of the root system,—the usual result of culture in all highly concentrated solutions, and also in shortening the vegetative period with a premature ripening of the crop. The plants do not develop fully, the leaves turn yellow prematurely, and, accordingly, the yield is smaller than it would otherwise have been.

g. Excess of Carbon Dioxid.

Experiments on the effect of carbon dioxid content in the air and soil, greatly in excess of the normal, have led to contradictory results. While some observers have recognized only injurious effects, others report a satisfactory development. These apparent contradictions may be due to the fact that with carbon dioxid, as with all other nutritive substances, the effect depends upon how simultaneous the activity of all the other growth factors may be. The activity of the plants is generally adjusted to the small normal carbon dioxid content of the air[2]. They sometimes respond to a greater increase of carbon dioxid by arresting growth, sometimes by increasing it, depending upon whether the carbon dioxid increase occurs suddenly, or gradually, and whether the amount of light and warmth, water and nutrients permits the individual utilization of the increased amount of carbon dioxid. Godlewski[3] has substantiated this point of view by experiment.

Our hot bed plants furnish abundant proof of the favorable affect. According to E. Demoussy's investigations[4], this is due not only to an increased warmth, but actually also to an increase of the carbon dioxid in the air of hot beds, sometimes amounting to more than two thousandths parts. In comparative cultures, the air of the hot bed, which after careful testing showed no ammonia, had furnished nearly three times the harvested weight of plants grown in ordinary air under otherwise similar conditions.

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[1] See lecture by H. Roemer; cit. Blätter f. Zuckerrübenbau 1905, p. 229.

[2] Brown, F., and Escombe, F., Der Einfluss wechselnden Kohlensäuregehaltes der Luft auf den photosynthetischen Prozess der Blätter und auf den Wachstumsmodus der Pflanzen. — Farmer, J., & Chandler, S., Über den Einfluss eines Überschusses von Kohlensäure in der Luft auf die Form und den inneren Bau der Pflanzen. Proceed. R. Soc. LXX. cit. Centralbl. f. Agrik.-Chemie 1903, p. 586.

[3] s. Sachs, Arbeit. d. Bot. Instituts zu Würzburg. Part III.

[4] Compt. rend. de l'Acad. d. sciences 1904. cit. Centralbl. f. Agrik.-Chemie 1904, Part 11, p. 745.

The fact that experiments in sterilized soil, as contrasted with those in non-sterilized soil, resulted in much smaller amounts of yield, is ascribed by Demoussy to the killing of the micro-organisms which, by their activity, contribute to the decomposition of the carbon dioxid production. It is also probable that the growth of plants close to the ground is favored by the carbon dioxid constantly given off by the soil, since it has often been determined that air at the surface of the soil contains more than three ten thousandths carbon dioxid.

In air in which the carbon dioxid has a tension five times above the normal, a great many different plants increased about possibly 60 per cent. more in weight than they did in ordinary air. These also blossomed earlier and more abundantly[1].

If plants, which naturally behave differently according to species and individuality, are no longer able to utilize the carbon dioxid given them, their life functions must cease. Kosaroff[2] distinguishes between a specifically injurious effect, and one due indirectly to the decrease of the partial pressure, or rather, the removal of oxygen. As a result of the depression of the transpiratory current, the plants wilt. Böhm[3], like Saussure, observed that germination was retarded, in that with an increase of carbon dioxid, the roots and stems constantly became shorter and shorter. The chlorophyll formation and assimilation were considerably decreased.

Neither can geotropism be perceived in articulated plants (Gramineae Commelinaceae, etc.) in a carbon dioxid atmosphere, nor may a stimulus, found in the air, initiate any bending[4].

Finally, when carbon dioxid begins to be excessive, the effect may first be beneficial, then later gradually harmful. Reference should be made here to the experimental results obtained by Brown and Farmer[5]. They observed that, with an increased carbon dioxid content in the air, all the parts containing chlorophyll became a darker green after 8 to 10 days, and the starch content increased, but the internodes became short and thick, the leaves rolled up even to the point of deformity, the flower buds dropped, or their primordia were not formed.

Such conditions as are given in the experiment need scarcely ever be feared in practice. Such cases occur most frequently in hot beds where the manure, needed to raise the temperature of the beds, sets free too much carbon dioxid. This trouble may be overcome by proper ventilation, (even on frosty days.)

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1 Demoussy, E., Sur la végétation dans des atmosphères riches en acide carbonique. Compt. rend. CXXXIX, p. 883.

2 Kosaroff, P., Die Wirkung der Kohlensäure auf den Wassertransport in den Pflanzen. Bot. Centralbl. 1900, Vol. 83, p. 138.

3 Sitzungsber. d. Wiener Acad. 1873 vom 24. Juli.

4 Kohl, Die paratonischen Wachstumskrümmungen der Gelenkpflanzen. Bot. Zeit. LVIII, 1900, p. 1.

5 Loc. cit.

SECTION II.

INJURIOUS ATMOSPHERIC INFLUENCES.

CHAPTER IV.

TOO DRY AIR.

INJURY TO BUDS.

Although in house plants, for example, we have constantly met with the lack of sufficient atmospheric moisture as a factor in the production of the phenomena of disease, it has as yet been but very little taken into consideration.

The direction in which continued great scarcity of atmospheric moisture makes itself felt may be seen from the peculiarities of the xerophytes. As an example of this, we will mention Grevillius[1]. He found in the plants of a treeless lime plateau a thickening of the epidermis and its wax coating, or, as a substitute for this, a great increase of pubescence. These characteristics are more marked in leaves near the top of the stem. The epidermal cells, in contrast to normal forms, usually have somewhat smaller lumina. The palisade cells are broader and more closely joined to one another, the intercellular spaces are smaller; the mechanical tissues in the branches and petioles are better developed, the pith less; it has smaller cells but is richer in starch. These changes, in fact, occur almost always in connection with a great lack of moisture in the soil whereby it is hard to judge which is due to the dryness of the air alone and which to the excessive transpiration conditioned by it. However, we find various processes setting in when, with a sufficient supply of soil moisture, the air is constantly hot and dry; these will have to be discussed here. They are in part phenomena of arrestment in the life of the buds or in the conditions of germination; in part disturbances in the mature leaves which lead to the falling of the leaves in summer.

Two stages must be noticed in the life of the buds and the development of the young shoot after the bud has unfolded. If a considerable dry period

[1] Grevillius, Morphologisch-anatomische Studien üb. d. xerophile Phanerogamen-Vegetation der Insel Oeland. Englers Jahrbücher 1897, XXIII, p. 24.

sets in in the early spring when, as a rule, it is continued by a persistent East wind, the opening of the buds, dependant on the alternating action of sunshine and rain, will be delayed. The gummy masses in the bud scales of many varieties of trees, usually due to the gelatination of the tissue, must be softened by rain to facilitate the development of the buds, while the resinous and partially balsam-like products of this softening in the scales, warmed by the sunshine, give way at the same time to the pressure of the buds. In continued dry and windy, spring weather, the buds unfold more slowly because the necessary growth of the inner side of the scales is prevented so that they cannot turn back far enough.

In the second kind of injury, the young tip of the shoot, just appearing, is suddenly exposed to the sharp rays of the sun and to very great evaporation in abnormally dry air, after the protecting scale has been thrown off. In order to understand this process, we give a few illustrations from Grüss[1].

In Fig. 67 is shown the cross-section through the bud covering of the oak; in Fig. 68, one through *Pinus Mughus*. It is easy to distinguish the different scales firmly overlapping above the strongly developed epidermis of the outer side and, by comparing the two bud coverings, the increase of precautionary protection in the conifers is found to take place by means of the deposition of masses of resin (*h*). In the cross-section of the individual covering scales it is noticed that their outer or, later, under side possesses especially strongly developed elements. In the pine, the *epidermal cells* have been very greatly thickened sclerenchymatically. The bud covering of the winter oak is composed of 8 separate scales, and its cell layers found underneath the epidermis are so strongly thickened that the lumina have almost disappeared.

Fig. 67. Cross-section through the bud covering of **Quercus sessiliflora**, Sm. (After Grüss.)

Fig. 68. Cross-section through the bud covering of **Pinus Mughus**, Scop. (After Grüss.)

[1] Grüss, J., Beiträge zur Biologie der Knospe. Pringsheims Jahrib. f. wissenschaftliche Bot. Vol. XXIII, Part 4, p. 637.

The summer oak, *Quercus pedunculata,* Ehrh. behaves somewhat differently. If, in the Spring, a basal growth increases the sclerotic elements, the covering scales show a certain stiffness and remain longer attached to the growing shoot. They thus protect it longer from the dangerous fluctuations in temperature. The oak in the warmer Mediterranean countries, *Quercus Ilex,* L. hardly shows the sclerotic elements in its scantier bud coverings, and sometimes they are entirely lacking. In this we are concerned with protection against the summer drought period and find it in the hairs, which develop from the epidermis, and also the cork layer, which develops from the subepidermal tissue.

Before the leaves burst out from the bud, the scales, bent together like a roof, are simply small leaves reduced to stipules, but when the leaves break out, the under side grows further at the base, while the sclerotized outer side does not do so. Consequently the base of the scale, drying from the edges backward, become fleshy, cushion-like and, like a prop, presses the scale outward. This is the time of danger, since even the delicate vegetative cone is exposed to the fluctuations of temperature, and almost without protection. This explains the internal ruptures made by the action of the frost, sometimes found in the spring[1], and also the phenomena of shrinking from drought, resulting from constant sharp East winds.

No matter in what way the protective apparatus of the bud scale is formed in the various species, whether from sclerotic cell layers or from cork layers, layers of hair or masses of resin, the fact holds good that this apparatus *develops differently* in different years, according to the weather and the amount of nutriment at the time of its formation, and, accordingly, is of different protective power in the following spring. If, for example, the summer has been moist and cloudy, the covering scales tend to development towards the nature of the green leaf and the cells become larger or less thickened. In spring they react more quickly to the increase of turgor of the tissue and separate from one another more quickly. Thus the growing point is exposed prematurely to inclement spring weather, and so loses too rapidly the protection against its power of transpiration.

This factor must not be underestimated, for Grüss reports[2] that, when he removed the strongly developed outer scales from an oak bud, he noticed that the bud was destroyed with great regularity, even if the temperature did not fall and there was present sufficient moisture. Also the inner, more delicately walled coverings became dry since they were not accustomed to the increased transpiration. Uninjured buds kept under similar conditions (on cut twigs) developed further.

Experiments with beech buds, from which the whole covering had been removed, showed that the young, exposed leaves kept fresh much longer than those of the oak. This is due to the pubescence of the young beech leaves, which protect them from too great transpiration and the con-

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1 See chapter on the Action of Frost.
2 Loc. cit. p. 649.

sequent drying. This view is supported also by the observation of Grüss, that, in *Aesculus Hippocastanum,* the young leaves, known to be very thickly pubescent, will develop normally after the removal of the bud covering. The effectiveness of the resin covering is seen from an example of *Abies Pinsapo,* Boiss. When the resin had been removed from the buds by carbon disulphid, they dried up.

It may now be asked how such irregularities in the unfolding of the buds can be combatted practically.

The formation of the bud covering cannot be influenced and the dangerous fluctuations in temperature and atmospheric moisture in spring cannot be controlled. Nevertheless, we think a precautionary measure might indeed be adopted in forestration in order to moderate the extremes of transpiration. In the first place, the soil should retain its natural covering of moss or litter, since in this way the soil moisture is preserved, and a damp atmosphere made possible. Hence it might be advisable not to clear away all the leaves, etc. Finally, however, and especially in younger plantations, it might be advantageous to retain protective forests on the side of the tract exposed to the strong spring sun. Among such protective trees the rapid and loosely growing birch is especially useful.

In garden plants, naturally, one can control conditions very much better. In this connection, attention should be called for the present only to the fact that one should not attempt to replace the uniformly great loss from transpiration by increasing the water at the roots. That does not work well and plants are found to dry up which have an excess of water at the roots. The only natural means is *artificial shading.*

Defoliation Due to Heat.

Observation shows that every year from spring on the foliage falls from our deciduous trees. In city planting this is especially noticable in *Acer Negundo* and the slightly developed inflorescences of the linden show this almost at once, sometime before the "linden blooms." The process is less striking, but constantly present in other deciduous varieties. Wiesner[1] gives this constant dropping of separate yellow leaves the special name of *"the summer defoliation"* and sees its cause in the changes in the sun's altitude. I think that other causes can also operate here, for, while the summer defoliation usually sets in predominately after the 21st of June, observations show that, for example, according to Wiesner's statements, in *Acer Negundo, Acer Californicum,* and related species, the leaves first formed may be dropped even in May and at the beginning of June.

As long as this loss of leaves is slight in comparison with the whole foliage of the tree, it has no pathological significance. Experiments have shown that it is a perfectly normal phenomenon for the leaves on a branch to complete their cycle of growth at different periods. Thus some would

[1] Wiesner, Jul., Über Laubfall infolge Sinkens des absoluten Lichtgenusses (Sommerlaubfall). Ber. d. D. Bot. Ges. 1904, p. 64.

fall earlier, some later. Those produced first in the spring are weak in their formation, being smaller and not so brightly colored; hence they soon reach their full development, when their assimilation is arrested, as the stronger leaves, produced later, cut off their light. Then the tree frees itself of the organs incapable of working.

However, the summer defoliation is to be considered as a phenomenon of disease when it becomes extensive and suddenly attacks the well developed foliage in full sunlight. Late frosts and more often a continued period of drought, combined with great heat, are among the causes of summer defoliation. Wiesner distinguishes the latter form as *"defoliation due to heat,"* clearly a result primarily of excessive transpiration with an unequal decrease in the supply of water in the trunk.

I found examples of defoliation due to heat in the trees planted along the streets, especially among the lindens, in spite of abundant watering. From this it is evident that actually the dry air with abundant sunshine should be assumed to be the injurious factor. With deficient water supply in the soil alone the foliage dies from summer blight but usually remains hanging on the tree.

The linden, despite its beauty, is not to be recommended as a street tree because of its especial sensitiveness. The summer linden shows earlier and more severe effects than the winter linden, and after the appearance of summer heat, almost without exception, is found covered with the fine webs of the weaving mite (*Tetranychus telarius*). In many trees aphids occur in immense quantities. After defoliation, from which only the tips of the branches are excepted, there is manifest a prematurely dormant period. As soon as the weather becomes cooler (or when the streets are abundantly watered during the hot period) a second growth appears in which the development of lateral buds can push off the hanging leaves (*defoliation due to growth,* according to Wiesner). In wet autumns the wood of this second growth does not ripen properly and is easily injured by the winter frosts.

In order to avoid these conditions it is advisable to plant elms rather than lindens along the streets. If these conditions appear along avenues of older trees, which cannot be replanted, the streets must be sprinkled as frequently as possible. Spraying under heavy pressure in the late evening may prove to be especially useful. I consider that consistently following this measure will prove the most effective prevention of vermin attacks.

Honey Dew.

According to observations made up to the present, a disease must be included here which has often[1] been described under the name *"honey dew"* (*Melligo, Melaeris, Ros mellis*) and which has been traced to very different causes. This disease is characterized by the appearance of a sugary coating

[1] Saccharogenesis diabetica; Unger, Exanth. p. 3.—Honning Dugen, Fabricius Kiobenh. 1774.—Le Givre, Adans, cit. bei Seetzen: Sistematarum generaliorum de morbis plantarum. Göttingae 1789.

on leaves, blossoms and young twigs of woody and herbaceous plants usually covering the outer surface of the organs, sometimes as a shining uniform varnish, sometimes in the form of yellowish tough drops. Meyen[1] relates that for some time the theory expressed by Pliny was accepted, namely, that the honey dew was an actual falling from the air, occurring in the dog days especially and coating not only the plants, but even the clothing of men. J. Bauhin contradicts this theory and calls attention to the fact that only isolated plants or species in any region become diseased. After the excretion of a sweet sap from the anus or the abdominal tubes of the aphids had been observed, they were considered to be the cause of the disease and at the time it was observed that aphids and honey dew were frequently found together. To this, however, was opposed first of all, the fact that the aphids usually occur on the under side of the leaf, the honey dew, chiefly on the upper side. However, this fact is no very certain proof since the aphids of the under side of the leaf can sprinkle the upper side of the leaf lying next below. But gradually the observations on honey dew were increased on isolated outdoor and indoor plants on which no aphids could be found or upon which they did not appear until sometime later. Hartig's observation, made in 1834, is interesting in this connection. A rose plant, which had not been taken from the house, secreted small drops on the under epidermis of the leaves from which the sugar was separated in rhomboidal or cubical crystals. In this the green color of the leaves changed to a grayish one, due to the disappearance of the chlorophyll in the mesophyll at the secreting places and to the appearance of clear drops in the cells. Treviranus[2], in the same way, frequently found such sugary secretions in the warm, continuously dry air out of doors as well as in greenhouses, on white poplars, lindens, orange trees, distils (*Carduus arctioides*) and cited still older observations by Lobel, Pena, Tournefort et al., according to which honey dew occurs on olive trees, varieties of maple, walnuts, willows, elms and spruces. He, and later Meyen, were convinced that the drops containing sugar were secreted directly from the epidermal cells, to which the former observers also added that the stomata did not take part in this secretion. Further observations on honey dew occurring in very different plants, especially oaks, were furnished later by Gasparrini[3].

The honey dew on the linden has been chemically investigated by Boussingault and that on the grape cherry (*Prunus Padus*) by Zöller[4]. Boussingault found that the honey dew, collected at two different times, differed quantitatively in regard to the different substances; from which fact it is evident, that the secretion does not always have the same percentage composition. But the nature of the substance seems to change also, for although Boussnigault found only cane sugar (48 to 55 per cent.), invert sugar (28 to 24 per cent.), and dextrin (22 to 19 per cent.), Langlois

[1] Pflanzenpathologie, 1841, p. 217.
[2] Physiologie der Gewächse, 1838, Vol. II, Part I, p. 35-37.
[3] Sopra la melata o trasudamento di aspetto goommoso etc. Bot. Zeit. 1864, p. 324.
[4] Ökonom. Fortschr. 1872, No. 2, p. 39.

also found mannit as one constitutent of the honey dew on the linden. Czapek[1] collected the results of more recent observations. From this it may be concluded that the composition of the honey dew varies in different plants.

A harmony of the theories as to the causes of the phenomenon has not been obtained as yet. While Büsgen[2] studied carefully the aphid stings on plants, he proved that the animals secrete through the anus much larger amounts of honey dew (the secretions of the abdominal tubes are waxy) than is usually assumed, and, on this account, he concludes that real honey dew depends only on aphids. Bonnier[3] made some experiments which showed an artificial production of honey dew without the intervention of the animals.

Büsgen says the peculiarities of the cuticle allow neither an osmosis or distillation of sugar saps from the interior of the cell nor, as Wilson assumed, an osmotic withdrawal of liquids through drops of sugar to be found on the surface of the leaf, such as are formed by the excretion of the aphids. This statement, however, does not consider the fact that the smooth surface of the cuticle can become broken and that secretions in individual cases can find their way through the stomata. Bonnier's results prove the later case. Leaves which had been exposed to great differences in temperature (conifers, oaks, maples, etc.), showed under the microscope, when examined by direct illumination, the formation of nectar-like drops from the stomata when the light was sufficiently strong.

My own observations confirm the occurrence of honey dew without the intervention of aphids. In one case I found an abundant formation of honey dew on the older leaves of pear seedlings grown in water cultures and exposed to the hot July sun. This observation showed that deficient soil water was not necessarily a factor. I believe that honey dew is produced if there is a sudden excessive increase of transpiration in strongly functioning active leaves, caused by a strong light stimulus, and brings about too high a concentration of the cell sap. If the disturbance continues beyond a certain point, the leaf suffers permanently and falls prematurely. In another case the rain gradually washed the sugar coating away, which made possible an attack of the black fungi (sooty dew). The production of honey dew is not always dependent upon extreme and absolutely high temperatures and strong light stimuli, but sudden great contrasts as, for example, the sudden shock to an organism caused by an intense morning sun following a very cool night, which had suppressed its activity.

Shading would be the best preventative measure and repeated sprinkling an effective remedy.

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[1] Czapek, Fr., Biochemie der Pflanzen. Jena. Gustav Fischer. 1905, Vol. I, p. 408.

[2] Büsgen, M., Der Honigtau. Biolog. Studien an Pflanzen u. Pflanzenläusen. Sond. Biologisches Centralbl. Vol. XI, Nos. 7 and 8, 1891.

[3] Bonnier, G., Sur la miellée des feuilles. Compt. rend. 1896, p. 335, cit. Zeitschrift f. Pflanzenkrankh. 1896, p. 347.

Probably the much dread *Mafuta disease* of the sorghum millet (*Andropogon sorghum*) in German East Africa belongs here. The word Mafuta means oil. Honey-like excretions are found on leaves and stems. These give rise to a sooty coating[1]. Other plants also suffer especially in times of drought.

Heart Rot and Dry Rot of Fodder and Sugar Beets[2].

The heart rot of the sugar beet should be considered as a phenomenon usually related to honey dew. It is found usually in hot Julys in rainless periods and is characterized by the death of the heart leaves. These have not grown to half their normal size. The dying foliage suddenly becomes black. In severe attacks the whole leaf area dies, but, as a rule, the plants develop new foliage. In addition to the affection of the leaves, the body of the beet is attacked by a decomposition or dry rot. The beet, near its head end, has spots which can deepen as the tissues decompose, and finally destroy the beet. Of greater agricultural significance in this connection is the fact that a part of the non-reducing sugar disappears from the beet and another part is converted into reducing (grape) sugar[3]. If the rainy weather sets in at the right time, the dead tissue can be thrown off through the formation of cork.

If the healing process does not set in soon enough, so that a long continued autumnal dampness can exercise its influence on the decayed places, the process of destruction of the beets, which are poorer in sugar, is also continued in the storage pits.

Most observers are inclined to seek the cause of the trouble in fungi, since mycelium is often found in the diseased heart leaves[4]. Frank especially defended the fungi theory and wished to make two species responsible for it: *Phoma Betae*, Frank[5] and *Fusarium beticola*, Frank. It is certain, however, that the first stages of the disease of the heart leaves are without fungi and bacteria, and the parasites later, during damp weather, occasion an advance in the destruction of the tissue. However, when the beet plants are healthy, the fungi cannot attack them. Only when evaporation is sufficiently increased and the absorption of water sufficiently decreased do the conditions arise which predispose the plants to attack by fungi.

Practical workers state that the addition of lime also in the form of waste lime favors the attack of the disease. We have very instructive field experiments[6] along these lines in which some areas were limed, and some not. Where lime was used, the beets were diseased, where there was none, the crop was healthy.

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1 Busse, W., Weitere Untersuchungen über die Mafuta-Krankheit der Sorghum-Hirse. Aus "Tropenpflanzer," cit. Zeitschr. f. Pflanzenkrankh. 1902, p. 82.
2 See Vol. II, p. 240.
3 Frank, A. B., Kampfbuch. 1897, p. 131.
4 Prillieux et Delacroix, Complément à l'étude de la maladie du coeur de la Betterave. Bull. Soc. mycologique. VII, 1891, p. 23.
5 syn. **Phoma sphaerosperma**, Rostr., **Phoma Betae**, Rostr., **Phyllosticta tabifica**, Prill. et Del.
6 Zeitschr. f. Pflanzenkrankh. 1895, p. 250, 1896, p. 339.

Also the location itself has often been found to favor the appearance of the disease, since on field ridges with a gravelly underground, or declivities from which the water runs away quickly, often only dry rotted beets are produced. The different varieties are proved to be susceptible to different degrees; the Vilmorin sugar beet is said to be especially susceptible; varieties with smooth leaves spread flat on the ground and long roots should be preferred in threatened regions[1].

Sasse[2], as a result of his very thorough field experiments, states that vapor and deep cultivation prevent the outbreak of dry rot. Opinions vary greatly as to the influence of fertilization. In my opinion, the variation is explained by the varying action of the same fertilizer on different fields, and dependent on the weather. Fertilizers making the soils more porous, increasing their capacity for warmth and decreasing their power for retaining water, tend to favor the development of dry rot; this can occur with waste lime[3]. The same fertilizers are satisfactory in heavy soils. Fertilization with kainit has been most questioned. It is emphasized that the soil will actually retain water better after fertilization with commercial manures, i. e. offer greater resistance to the influence of drought, and yet not infrequently where kainit fertilization has been used, the first heart rot of the beets will be found.

In my opinion there is a natural explanation for this phenomenon. Kainit tends to develop leaves extraordinarily; hence, with a continued dry period, the extensive leaf area withdraws water very quickly from the root system, causing an injurious concentration of the cell sap. Analyses have shown that, with a high potassium content in the leaves, the dry rot appeared more marked, the smaller the proportion of phosphoric acid present.

Therefore, the choice of land which dries quickly may be a preventative measure for this disease. When the soil is light those materials, which heat the soil (lime, separator ooze) must not be given directly to the beets. With the appearance of dangerous droughts, one should decrease the drainage since, ordinarily, it would not be practical to always water the crop. A further condition should be considered, namely, whether the evaporation of the plants can be reduced by removing the older leaves, or by shading with straw mulching.

Faulty Development of the Blossoms.

Much oftener than is generally supposed, great atmospheric dryness manifests itself in blossoms, especially double flowers. If specimens of the same species with single and with double blossoms in the same position be compared (fuchsias, petunias, tuberous begonias, roses, etc.), it will be observed without exception that the single blossoms develop more rapidly

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1 Bartos, W., Einige Beobachtungen über die Herz- und Trockenfäule, cit. Centralbl. f. Bakteriologie 1899, p. 562.

2 Sasse, Otto, Einige Beobachtungen aus dem praktischen Betriebe betreffs Auftretens der Herz- oder Trockenfäule. Zeitschr. f. Pflanzenkrankh. 1894, p. 359.

3 Richter, W., Über die Beziehungen des Scheideschlamms zum Auftreten der Herzfäule der Rüben. Zeitschr. f. Pflanzenkrankh. 1895, p. 51.

and quickly. The slower and more retarded development of double blooms may be traced to greater distribution of the water and nutritive substances conveyed through the petioles over a more considerable leaf area. The loss in transpiration, due to the increased number of petals, is greater and can in no way be replaced by supplying water to the roots. Consequently, the organs develop more quickly; they become ripe prematurely and cease growing before the blossom has been completely developed. On this account *half open blossoms* often fall where there is great atmospheric dryness. This should not be confused with the dropping of the blossoms, due to excess of water. In the latter case it may often be observed that both the blossoms and peduncles fall. With excessive transpiration in a very dry atmosphere, the petals fall where they join the peduncle after having turned brown there.

When, as is often attempted in greenhouses, an artificially moist atmosphere is produced by abundant watering of entire plants, their condition is improved only if the flower pots stand on the soil, since the vaporizing dampness from the soil keeps the atmosphere constantly moist. But if the pots stand on wood, iron or stone, the blossoms shrivel up in spite of the watering and a Botrytis growth is found where the petals loosen. This leads consequently to erroneous conclusions since Botrytis diseases are usually accompanied by great atmospheric humidity.

The double staminate blossoms of tuberous begonias fall in excessively dry air, and form one of the most striking examples of the difficulty. I observed this often in the dry summer of 1904 in places which had never had direct sunlight. That the falling of the petals was actually due to dryness of the air was shown by an experiment in which plants were used, which usually drop their blossoms at the time of opening. They retained and developed them, however, if placed over broad basins filled with water.

The pistillate blooms always mature. The first indication that the staminate blossoms are going to fall is that the bud does not straighten up but remains drooping. With the hand lens a small brown ring may be seen at the union of the calyx and peduncle. There the young tissue is found to be deep brown, its walls and contents collapsed. At the calyx, the shrivelling and tearing of the tissue forms large holes until finally the petals hang only by a few shreds of tissue. In the individual petals, the vascular bundles also seem deeply browned even at the places which are still not discolored and apparently fresh. This drying of the base is really a premature end of the life cycle, since the cell contains only scanty flakes of protoplasm. Near the dead tissue there is an abnormal accumulation of asymmetrically formed, separate crystals of calcium oxalate, as the final residue of the organic substances consumed in respiration.

A second kind of defective blossom development, resulting from dryness, was observed in the Liliaceae and Amaryllideae. In these instances the perianth remained stuck together at the apices. Although the rest of the blossom was normally developed and colored, the tips of these perianths

turned yellow, shivelled up and dried into a mass which finally crumbled. The injury is horticulturally of significance only when the blooms are forced and large individual blossoms are desired as in *Lilium aureum, Lilium longiflorum and Hippeastrum robustum,* Dietr., etc.

In that species which is known among gardners as *Amaryllis Tettaui* and is often grown as a house plant because it blooms freely, I observed more carefully the mechanics of opening and incomplete development during drought.

The three outer tips of the brick red perianth begin to separate from one another at their base on the day before the blossoms are completely opened; hence the large conical flower bud first of all shows three slits. The tips of these three outermost petals, however, remain stuck fast together even if the process of separation from one another is so hastened by the increased growth of the innerside of the perianth that this is curved outward like a pouch. In this convexity, which becomes constantly greater, lies a great elasticity which would be able to separate the gummed tips from one another and, in normal cases, actually does tear them apart. The strength of this elastic power, produced by the basal epinasty of the perianth, is demonstrated if the still gummed apices of the three tips are cut off about forty-eight hours before the normal time of opening. Then, within 10 minutes, the individual tips have separated 1.5 to 2 cm. from one another, i. e. the corolla has begun to open. The resistance offered to this strong elasticity arises from the fact that the green apices of the three outermost tips are anchored to a strong cone about 5 cm. long. Sometimes this cone is thimble shaped. There is a heavy growth on the underside of each tip which curves out like a ridge, and corresponds with a midrib, making a very fleshy growth on each tip.

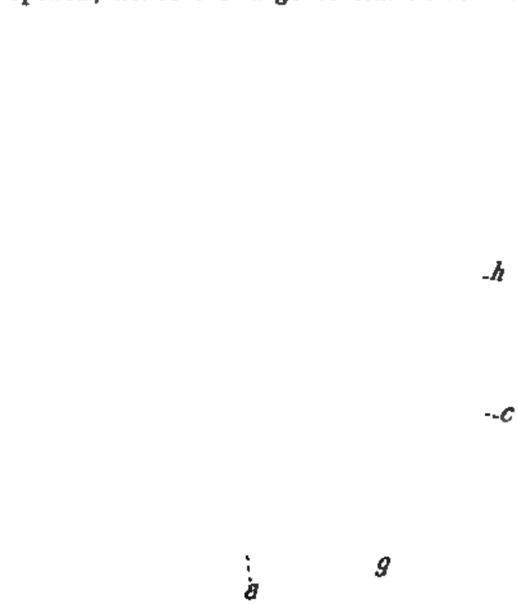

Fig. 69. Cross-section through the apical region of a still closed blossom of **Hippeastrum robustum.** Explanation of the letters in the text.

Fig. 69 shows three of the perianth tips, touching each other with their keel-like wedges (a). These wedges contain no vascular bundles. These lie (g) frequently in groups of 3 or 4 peripherally in the real laminal part. The individual laminal halves at both sides of the fleshy median ridges are curved inward and touch the adjacent peripheral tip with their edges (r);

these are green, while the fleshy cushions at the center (*c*), containing the largest parenchyma cells, seem colorless. In contrast to the abundant small grained masses of starch in the rest of the tissue, the cushions display only a few large starch grains. The epidermis is normally flat walled at the outside of the peripheral tip, but, on the ventral side, at the beginning of the development of red coloring matter, shows a papillary outgrowth. Although this grew out to distinct papillae, mutually interlocking, like clogged wheels, on the cushion-like raised places (*a*), it shows scarcely any elongation on the flat laminal part.

In this close interlocking of the papillae of the tip of one part of the perianth with those of the others may be seen the reason for anchoring these tips so firmly together. An elastic strain loosens the tips since these papillae grow rapidly to conical hairs, thus breaking the connection. In the cavities (*h*) which the outer petals leave free, lie the tips of the three inner ones, whose epidermis, however, develops papillae sooner than that of the outer ones. The mutual resistance of the out-growing papillae favors the separation of the inner tips of the perianth and, therefore, the blossoming.

When the atmsophere is dry, the primordia of the papillae may still be found, but they do not develop into conical hairs; hence the tips of the petals remain united and gradually shrivel up.

House Plants.

The typical picture of a house plant which meets our eye shows browning and drying leaf tips. Where gas is burned, usually one is inclined to lay the blame on the gas. As a fact, the dryness of the air in the room is the cause and the condition is as marked in dwellings where gas is not used. The fact that plants, especially the so-called foliage plants, die after the tips become brown and dry, may be explained as due, not to the atmospheric dryness, but to the attempts of the grower to get greater moisture in the air by very frequent watering. However, the plants get no benefit from this increased supply of water. They can use more water and transpire it only when the tissue develops more abundantly, resulting in a more vigorous assimilation and a greater production of leaves. The dryness of the air, however, inhibits this very development of the leaves.

When the foliage of tropical climates (many foliage Begonias, Hoffmannias, Ruellias, Marantes, etc.), are brought from the moist conservatory into a room of the same temperature, the development at once ceases. The older leaves begin to curl back; the younger ones roll up their edges and remain smaller than those previously formed. The apical growth of the shoots is retarded; all processes of elongation are reduced. It is peculiar that with many plants (for example, many bushy Begonias) the blossoms, produced in dry air, either do not open at all or only incompletely, and finally fall off without having become diseased. This process may also be observed out of doors. The dormant period of the plant sets in more

quickly, and, when the new vegetative period begins, the development of the buds is retarded and often entirely prevented. With such activity in the parts above ground, the roots will rot if given too abundant water.

Various methods have been proposed to overcome the injurious influence of the dry air in the room, such as to spray frequently or to cover the plants at night with damp cheese cloth, etc. However, such methods have not proved sufficiently satisfactory. I obtained best results by using Wardian cases or by setting the plants over water. Recently flower tables have been used in which the plant stands on a zinc box filled with water, the top of which has been punctured full of holes. Through this, water vapor constantly rises between plants placed above it.

Hard Seeds in the Leguminaceae.

The hard-shelled condition of Leguminaceae seeds, not only those of the *Papilionaceae*, but also those of the *Mimoseae* and *Caesalpiniaceae*, can be considered as a natural protection against micro-organisms at a time in their development when they are most readily infested. All our wild growing Papilionaceae exhibit the same constructive principle and the hard-seeded condition becomes dangerous only when it prevents germination.

This hard-shelled condition arises from the special thickening of the palisade layer of the seed grain which, with its cuticle, forms the outermost covering of the seed shell. These columnar palisade cells, lying very close to one another, show in cross-section strongly refractive cross lines (*light lines*) of an especially dense substance. The cell content contains those substances which cause the coloring of the seed shell and to which great importance is ascribed as substances protective against parasite attacks. Next to the palisade layer, described by Nobbe as the *"hard layer,"* lies, on the under side, a layer of so-called hour-glass cells, next which are thin-walled cell layers with large intercellular spaces. These cells function especially in the swelling of seed. Corresponding to the gluten layer in grain seeds, we find in the majority of Leguminaceae seed, with the exception of the Phaseoleae, Vicieae and a few other varieties, according to Harz[1], the endosperm in the form of a hard, horny matter, which becomes slimy when placed in water. In the region of the scar, palisade cells and round hour-glass cells usually appear in two rows.

In this instance we follow Hiltner's experiments[2], which show that the hard-seeded condition preventing the rapid swelling of the seeds, naturally forms a protection against micro-organisms. Older lupine seeds, which were not absolutely hard-shelled but swell up only with difficulty, were soaked in water. The seeds which swelled each day were laid separately in the germinating box. This showed that those lupine seeds which swelled most rapidly and hence were not hard-shelled. almost always rotted, while

[1] Landwirtschaftliche Samenkunde.

[2] Hiltner, L., Die Keimungsverhältnisse der Leguminosensamen und ihre Beeinflussung durch Organismenwirkung. Arbeiten d. Biolog. Abteil. f. Land- u. Forstwirtsch. am Kaiserl. Gesundheitsamte. Vol. III, Part 1. Berlin 1902.

the percentage of germination was higher in those seeds where the swelling began later; due to the higher percentage of hard seeds.

It was concluded from experiments with eight year old clover seed which, on account of age, had already begun to grow dark, certain seeds having become brown and shrivelled, and which was sorted according to color, that the grains, which still had the appearance of completely fresh seed, gave the highest percentage of germination. Among the slightly discolored seeds, the brown ones germinated least and gave more than 90 per cent. of rotted grains. Among these seeds, a much larger percentage of the light-colored ones decayed than of the violet ones. This led to the deduction that the violet color of the seed covering offered a protection against bacterial attack.

The different percentages of hard-shelled seeds from a given variety over a period of several years, show the dependence of that condition on the weather. Hiltner, by drying the seed artificially at a temperature of 35°C., or over sulfuric acid, could increase the percentage of hard-shelled grain. This experiment showed the atmospheric condition required to produce the undesired hard-shelled seeds. This condition, therefore, resembles glassiness of grain. As the process of drying during ripening is hastened, more hard-shelled seeds might be formed.

In general practice, however, contradictory results are often found. In dry positions it was observed that the seeds of lupines, vetches, scarlet clover and the kidney vetch (anthyllis) (Windklee), in time become hard-shelled, while the finer clover seeds show rather the reverse. Hiltner's observation on artificially dried seeds explains this contradiction. The influence producing an increased toughness of the shell in thick-walled seed affects thin-walled seeds as well, but in them the shell splits, consequently increasing their small capacity for swelling; further Rodewald states that cold can decrease the hard-shelled condition of Leguminaceae seeds.

When one realizes that hard seeds can lie for years in the soil without germinating and that those, even less capable of swelling, may germinate so late that they cause a second growth, it will be evident that the seed grower must control the formation of hard shells to eliminate them. In the course of years, many methods have been recommended. Thus, for example, the seed should be laid in a 1 to 2 per cent. solution of sodium carbonate, to dissolve the silicic acid in the shell. Again, simply sift out the hard-shelled seeds, since they are all somewhat smaller than the normal ones which will germinate. Again, treating the seeds with hot water has sometimes been successful, sometimes not. Dipping in boiling water for one minute was injurious, but was beneficial when the seed was emersed for five seconds only. This treatment, however, over so short a time, cannot be entrusted to laborers. Potassium permanganate, dilute sulfuric acid, an ammoniacal solution of copper sulfate, have been as unsuccessful as the sodium solutions. On the other hand, Hiltner found concentrated sulfuric acid to be successful. The sulfuric acid injured only those seeds which

had been damaged in threshing, even if the seed was left for sometime in the acid. Frequently, treatment with sulfuric acid for half an hour will be sufficient if the seeds have been thoroughly wet by stirring. When the treatment is completed the acid should be thoroughly washed off with clean water and then immediately with lime water for at least 5 to 20 minutes. Microscopic investigations of seed treated in this way showed that (in *Acacia Lophanta*) the sulfuric acid had removed not only the cuticle but also the greater part of the palisade cells and had stopped before reaching the "light line." Yet the seeds could swell in water only when the acid had penetrated the light line in some places[1]. Therefore, this cell layer, present in the seed shell of all the Leguminaceae, according to Mattirolo[2], consisting of an especially dense cellulose, prevents the seeds from rapid absorption and elimination of water.

Connected with this innate hard-seeded condition is the ***hardening of the seed membrane*** during germination. With those seeds which, in germination, pushed their cotyledons above the soil, the cap-like seed shell is gradually pushed off, if it has been retained until the moisture is absorbed and thus remains flexible. But if a hot, rainless period sets in suddenly, the cap dries on the cotyledons, preventing their development, as well as the breaking of the young stem. In case it is not destroyed, it is twisted to one side. Lopriore[3] mentions here the germination of beans. I have observed similar phenomena in cucumbers, pumpkins, melons and the seeds of stone fruits. The retention of the dry, stony shell shows itself most destructively in the seedlings of plums, peaches and other Amygdalaceae. Sprinkling of the seed bed in the evening is, therefore, a precaution which should not be omitted.

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1 Hiltner und Kinzel, Über die Ursachen und die Beseitigung der Keimungshemmungen bei verschiedenen praktisch wichtigeren Samenarten. Naturwissensch. Zeitschr. f. Land- u. Forstwirtschaft 1906, p. 199.

2 La linea lucida nelle cellule malpighiane degli integumenti seminale. Torino 1885, cit. von Hiltner und Kinzel.

3 Berichte d. Deutch. Bot. Ges. 1904, Part 5, p. 307.

CHAPTER V.

EXCESSIVE HUMIDITY.

The Mode of Growth With Continued Atmospheric Humidity.

Older works have called attention to the fact that the structure and functions of individuals are altered by the influence of a high degree of atmospheric humidity in the same way as by the removal of light. According to experiments of Vesque and Viet[1], plants grown in moist air have longer, less branched roots, more delicate stems, leaves with longer petioles and smaller blades. The walls of the epidermal cells are less wavy; the cell rows of the mesophyll somewhat less numerous and without differentiation into palisade parenchyma. The whole tissue of the leaf grown in moist air is in every respect more uniform, while in dry air the difference between palisade and spongy parenchyma is clearly seen. The vascular bundles in the internodes are much more developed in dry air. This refers not only to the diameter of the whole bundle, to the number of ducts and their diameter, but especially to the hard bast fibres which may occur abundantly in dry air and be entirely lacking in moist air. Duval-Jouve[2] observed with grasses that dry, hot situations increased the development of the bast bundles, while, in moist places, this development is retarded. The authors named quote Rauwenhoff[3], who describes etiolated plants in this way. In comparative experiments with dry and moist air, under light bell-glasses, as well as shaded ones, it was found that, in darkness but in dry air, the plants were less spindling than those grown in the light in moist air, from which it is concluded that the form of the etiolated plants is due chiefly to deficient transpiration.

Brenner[4] expresses the same theory. In his experiments with Crassulae, he observed a tendency to decrease the succulency of the leaves in moist air, but to increase the upper surface. The cells of the stems were actually elongated. Wiesner[5] also found that the leaves of *Sempervivum*

1 Vesque et Viet, Influence du Milieu sur les végétaux. Annales des scienc. nat. Sixième série. Botanique t. XII, 1881, p. 167.
2 Botan. Jahresbericht 1875, p. 432.
3 Annal. d. scienc. nat. 6 sér. V, p. 267.
4 Brenner, W., Untersuchungen an einigen Fettpflanzen. Just's Bot. Jahresb. 1900, p. 306.
5 Wiesner, Jul., Formveränderungen von Pflanzen bei Kultur in absolut feuchten Räumen. Ber. d. Deutsch. Bot. Ges. 1891, p. 46.

tectorum considerably enlarged in an absolutely moist room and became markedly epinastic. The leaf rosettes were spread out because the internodes developed further. W. Wollny[1] found that a lessened thorn development occurs in normal leaves of *Ulex europaeus* as a result of continued atmospheric humidity. He also observed, however, that the chlorophyll content decreased as the leaves increased. According to Eberhardt[2], the number of chlorophyll grains is decreased if the stems become longer and the leaves larger. In a later work[3] this investigator summarizes his experiments as follows; moist air combines a reduction in the thickness of leaves and stems with elongation. The formation of hairs is decreased, that of blossoms and fruit retarded. Epidermal, bark and pith cells become longer, the intercellular spaces greater, the number of secretion canals smaller and the development of the wood less noticeable: A smaller production of lateral roots is noticed.

E. Wollny[4] also mentions that the time of blossoming and ripening is retarded and, by numerous experiments, strengthens the easily foreseen conclusion, viz., that the evaporation from plants and soil, under otherwise equal circumstances, is smaller, the greater the atmospheric humidity. It should be mentioned briefly in passing that in numerous cases abundant excretion of water takes place in the form of drops with the reduction of transpiration and by means of different devices in the various plants[5]. We frequently find this in potted plants which in the fall are brought into unheated greenhouses, when the leaves touch the rapidly cooling windowpanes.

Finally, I will mention the results of my own experiments[6].

In trees (pear) the whole new growth and also the different individual internodes and petioles were observed to be shorter in dry air, and the leaf blades more slender in moist air. In grains, the growth from seed was found to be somewhat less in dry air; the leaf number was also somewhat decreased, but the size of the individual leaves was increased longitudinally, while somewhat lessened in width. The same change in dimensions was also exhibited by the individual leaf cells. The influence of moist air elongated the leaf sheaths and also the individual blades, as well as the roots themselves, although the plants, even those exposed to dry air, stood in a nutrient solution.

The fact that the substance as well as the form of the plants will be changed with varying humidity is to be surmised as a matter of course. In fact, my experiments show that in moist air a lesser amount of green

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1 Wollny, W., Untersuchungen über den Einfluss der Luftfeuchtigkeit auf das Wachstum der Pflanzen. Inaugural-Dissertation. Halle 1898.

2 Eberhardt, M., Action de l'air sec et de l'air humide sur les végétaux. Compt. rend. 1900, t. 131, p. 114.

3 cit. Centralbl. f. Agrik.-Chem. 1904, Part 8.

4 Wollny, E., Untersuchungen über die Verdunstung und das Produktionsvermögen der Kulturpflanzen bei verschiedenem Feuchtigkeitsgehalt der Luft. Forsch. auf d. Geb. d. Agrikulturphysik Vol. XX, 1898, Part 5.

5 s. Bot. Jahresber. 25. Jahrg., Teil I, p. 76. Abh. von Nestler und Goebel.

6 Sorauer, Studien über Verdunstung. Forsch. auf d. Geb. d. Agrikulturphysik, Vol. III. Part 4-5, p. 55 ff.

matter was produced and that of this green matter, with plants in moist air, a large percentage occurred in the roots. In this, the aërial parts were richer in water. It was determined in regard to the functions, that evaporation in moist air is absolutely less; it is less also, however, per gram of green and dry matter produced, i. e. the plant in the production of one gram of material in moist air needs less water and this might occur because, under these circumstances, it produces it with few mineral substances.

A further experiment with peas[1] shows that the newly produced substance has an actually lower percentage of ash. The increased amount of water taken up by the plant, because of the strong evaporation in dry air, results in the plant's taking up in a given unit of time only half as concentrated a solution as it does with a weakened evaporation, when growing in moist air.

These results explain sufficiently why plants in moist air frequently succumb more easily to disease than plants grown in dry air. The plants are weaker in growth, richer in water and poorer in ash. Nevertheless, we have no insight into the diversity of the organic elements in the plant body. It is very probable that plants grown in moist air are richer in sugar, poorer in starch, as well as richer in asparagin and poorer in actual protein.

Influence of Moist Air on Plants Injured by Drought.

It has been supposed that plants which have suffered from intense drought can be most quickly restored to their former activity if placed in a very moist atmosphere. The following experiment shows the danger of this procedure. Cherry seedlings, which survived a long drought in sand cultures, at once showed an adjustment to the lessened amount of water supplied the roots. At first, without change of habit of growth, evaporation gradually decreased until the sand still contained possibly only 4 per cent. of the amount held when saturated. At this point the plants began to wilt, but, at the same time, evaporation ceased almost entirely. For example, at a temperature of 30°C. and abundant sunlight, a little plant which had formerly used daily about 8 g. water, evaporated only one decigram. After adding considerable water, the plant gradually increased the amount of evaporation. If, on the other hand, the drought continued too long, the leaves dried backward beginning at the tips, showing no discoloration.

If now, after being watered, the plants were brought into *moist air* they *did not* recover as I had thought they would at first. Those under the bell jars containing dry air had elevated the upper mature leaves, and the partially dried bases of the older leaves became turgid again; evaporation again set in slowly.

The gardener will find this observation of practical use in growing potted plants. Excessively dry plants after watering must not be changed in position. They must be somewhat shaded and they should not be placed in air practically saturated with moisture, since this will stop almost all activity.

[1] Loc. cit. p. 79.

Cork Outgrowths.

Cork is universally formed as normal tissue. It may increase abnormally, forming an excrescence under special circumstances. Even the regular formation of cork may be observed in varying amounts in different seasons. Attention should be given to the usual bark pores with their rounded complementary cork cells separated by intercellular spaces. These cells, showing for some time a cellulose reaction, are steadily reproduced during the time of growth. In winter, when the exchange of gases in the dormant bark is at its minimum, the production of the complementary tissue is stopped. In the autumn a layer of normal cork is formed from the cambium layer instead of the roundish complementary cork cells. With the awakening of bark activity in the spring, the cork cambium again forms complementary cork, rupturing the winter covering layer of the lenticel, just as, when the first lenticels were formed, it had split the epidermis. The more moist the air becomes, the more frequently the elongating complementary cork cells which attract water are formed on the surface of the bark. The longish, mealy, white excrescences, which may be rubbed off, are well-known. They occur on the smooth barked trunks of cherries and alders in damp habitats when the atmospheric humidity is increased and the foliar transpiration decreases.

At the base of the strong petioles of *Juglans regia, Sambucus nigra, Ailanthus glandulosa, Paulowna imperialis* and other trees, in the autumn, structures may be observed very similar to lenticels, only the cambium layer is missing (Stahl)[1]. Later research[2] has shown that cork cushions not only develop at the base of the petiole but, in many plants, at the veins of the under side of the leaf (*Ficus stipulata*) and finally also on the leaf-blades.

Now, although this formation of cork on the leaf-blade is a phenomenon almost as widely distributed as that on the stems with which it closely corresponds in structure and development, yet, in spite of the wide distribution, there is no pathological significance in these formations.

In these cork outgrowths of leaves, two types may be distinguished[3], either the cork layer with its dividing walls and its usually one-layered phellogen lies parallel with the leaf surface in the same plane,—when the cork excrescences are raised above the surface of the leaf in the form of warts; or the cork layer and especially its phellogen lies in the form of hour-glass-like, depressed zones in the interior of the leaf and usually becomes deeper and deeper. Many plants have both forms on the same leaf. In contrast to the regularity of the appearance and production of stem cork, emphasis should be placed on the accidental appearance of cork excrescence on leaves. Aside from the fact that the two above mentioned types can begin on the same leaf, there are also transitions between the two types. In

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[1] Stahl, Entwicklungsgeschichte und Anatomie der Lenticellen. Bot. Zeit. 1873, No. 36.

[2] Poulsen, Om Korkdannelse paa Blade. Kjöbenhavn 1875.

[3] Bachmann, Über Korkwucherungen auf Blättern. Pringsheim's Jahrb. 1880, Vol. XII, Part 2, p. 191.

fact, the cork outgrowths can arise in the same leaf in different layers (they usually occur in the sub-epidermal layer) and can have a different developmental course (Bachmann).

The external appearance of these cork formations on leaves, occurring on gymnosperms, monocotyledons, and dicotyledons, is very different. Sometimes there are small cones, sometimes sheets of cork, or strips of considerable extent. At times the cork excrescences, however, lead to the formation of holes which penetrate through the whole leaf (Ilex. Zamia, Ruscus, *Camellia axillaris, Peperomia obtusifolia, Eucalyptus Gunni* and *E. Globulus,* etc.). This perforation begins as yellowish points. In leaves with large intercellular spaces the cork formation is preceded by a growth of the parenchyma cells, in such a way that the intercellular spaces are filled by outpushings of the cell walls. If the cells with somewhat thicker walls in the rows of cork cells are changed by repeated division, the cell walls lose their original thickness. Frequently also the cork cells undergo a subsequent elongation after they have split the epidermis; the outer ones are stretched first.

In *Zamia integrifolia,* brown stripes, running parallel with the veins, are found on leaflets, splitting later into pieces or tearing down the whole length. These stripes are cork tissue which are not produced sometime after the leaflets have been torn and, thereby, representing wound cork, but are structures formed even embryonically in the younger leaf. Cork excrescences appear on both sides of the older leaves of *Dammara robusta,* but especially on the upper side, remaining usually small and flat. When young, they form small round spots on the green leaf surface and later become brown, when they are raised like little mounds. Finally, the epidermis and the immediately adjacent cork layers rupture. In *Araucaria Cunninghami* and more rarely in *A. Bidwilli,* small cork mounds may be found on older leaves of the previous year which can coalesce into ridges. In *Sciadopytis verticillata* and *Cryptomeria japonica* small cork warts occur at times also on older leaves; such structures may be recognized more frequently (but usually only on the underside) on the broad leaves of *Sequoja sempervirens.* In commercial horticulture, small point-like cork warts in *Cyclamen persicum* form a blemish as do also the chart-like etchings on the upper side of leaves of *Pelargonium peltatum* and in different kinds of foliage Begonias. These cork outgrowths appear, so far as observed, only in moist greenhouses and hot beds.

Among the monocotyledons, *Clivia Gardeni,* Hook and *Clivia nobilis,* Lindl., *Pandanus reflexus, Dichorisandra oxypetala, Billbergia iridifolia, Vanilla planifolia,* and other orchids exhibit cork structures which penetrate into the leaf. The cork excrescences on the leaves do not occur in the same amount in all specimens, nor to equal extent on all the leaves of the same plant, nor are the appearances constant each year. It must be concluded from this that special conditions cause this development of cork structures. So far as experience shows, they are due to an excessive atmospheric

dampness with a continued excessive supply of water at the roots and a decreasing intensity of light. An insight into the production of these phenomena may be found in the

Cork Disease of the Cacti.

This disease, often found in imported cacti, has become a constant source of anxiety for the European grower. It manifests itself in the different varieties of cactus, in the appearance of dry, papery places. These begin sometimes as raised yellow spots, or as spots remaining green and looking somewhat glassy. They widen out either into large cork colored surfaces, or become depressions which look like the scars of places injured by biting insects or animals. My special studies were first of all with *Cereus flagelliformis.* In severe cases the tips of the stems still seemed

Fig. 70. Piece of the trunk of a Phyllocactus which, on its under side, exhibits cork excrescences in the form of warts, while, on the opposite side, the process of perforation is beginning.

fresh and green, but at a little distance back from the tip a zone of rust colored specks began, starting usually below a thorn cushion. The specks gradually united into a rusty surface which ruptured here and there.

On the healthy part, the outer epidermal tissue consisted of two layers of irregularly 4 to 6 sided cells with thickened, heavily cutinized outer walls. Under this double layer was a single row of cells elongated tangentially and thickened like collenchyma. Then came the bark tissue containing chlorophyll and an abundance of crystals of calcium oxalate. Cork had been formed in the outer epidermal cells of the rust spots on the stems. The cork cells were wall-like in some places, irregular in others, like a cap which finally ruptured on the crest, thus rupturing the outer wall of the upper epidermal layer.

In other Cereus species, different sides of the stem seemed whitish and dry in wide stretches. Here cork layers formed in the epidermal cells in the angle of the stem; these were raised like papillae, while on the surface

of the stems they were warts. In young spots a change in the bark parenchyma was noticed. The outer cells were no longer distinctly collenchymatic and tangentially elongated but rather were broadened radially, thin-walled, poor in chlorophyll and partially divided. Because of this structure, the bark cells forced the cork tissue outward, causing whitish blisters or warts.

In Opuntia and Phyllocactus, the second variety of cork outgrowth is prevalent and is characterized by the *formation of depressed places* or by total perforation. Fig. 70 of a Phyllocactus illustrates both forms of cork excrescence. On the under side we see wart-like convexities, on the upper side the beginnings of perforation.

A cross-section of the flat stem shows the fleshy bark beyond the vascular bundle. In healthy places the bark is filled with starch (*st*) and contains numerous slime cells (*s*), calcium oxalate crystals and glands (*o*). When the wart begins to form, the bark parenchyma, by utilizing the starch, stretches, divides and pushes out the epidermis. The peripheral tissues (*i*), poor in contents, begin to die and a layer of flat cork cells (*t*) separates the dead tissue containing many intercellular spaces filled with air from the still living succulent tissue. At this point the progress of the disease stops and the stem seems covered with dry paper-like spots. If, however, there is no further removal of starch nor stretching of the bark parenchyma, and large particles die, the upper surface of the dead tissue finally ruptures, forming holes (*l*) which gradually become more and more depressed while the flattened cork cells (*t*) are constantly formed, growing inward. At *r* the bark changed, giving rise to the cork formation. There the change occurred earliest and most intensively and advanced rapidly into the interior of the leaf.

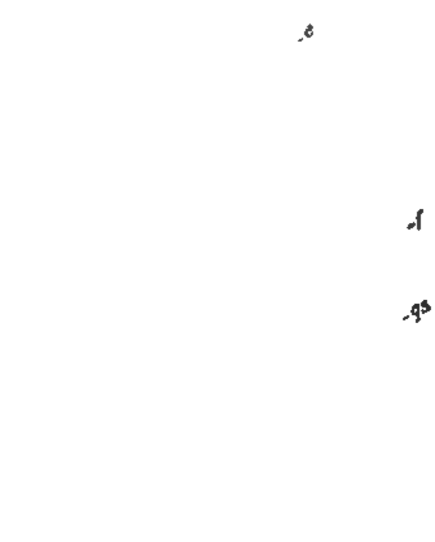

Fig. 71. First stage of a cork excrescence in Phyllocactus.

The process of cork formation is in itself a normal process in cacti when the stems reach a certain age. At the base of older stems there may be seen a formation of bark as in trees. The pathological feature is the formation of flat cork layers in the younger parts, at the expense of the bark. The cause may be found in the formation of tissue centers in the bark in which the cells elongate, while the starch breaks down and the cell contents are gradually impoverished.

Fig. 71 shows the first change in the tissues, in the formation of bark types of cork excrescence. This illustrates a piece of bark from Phyllo-

cactus with a spot differentiated from its healthy surroundings by a scarcely perceptible yellowish discoloration and a very slight convexity: *e*, indicates the epidermis; *l*, the collenchyma-like thickened cells; *o*, the crystals of calcium oxalate. The change begins close to the vessels (*g*) in the delicate venation traversing the succulent parenchyma. The darker spots in the parenchyma indicate the chloroplasts, which are found there either in the normal position along the walls, or collected in large refractive drops of cell contents (*o'*). Probably as a result of an accumulation of destructive enzymes and an increase in acid content, the sheath cells of the vascular bundle (*gs*) and those even further away (*i*) become poorer in contents and elongate, thus causing the first evidences of disease. Thus an inner growth is produced which, if it advances nearer to the upper surface, starts the formation of cork. If the cells, extending further back into the inner bark, become impoverished, more and more cork will be formed. Since the cork tissue cannot elongate as the organ grows, it must be of necessity rupture, and thus forms superficial warts as the cork formation advances. Grooves are formed by the strain of the tissues growing with varying rapidity and these deepen until there is a complete perforation as in deep scurvy of potatoes.

In order to control or eradicate this important disease of cacti, the water supply is lessened and air is given abundantly. Should there be a regular appearance of the disease covering several years, the plants must be kept dry even to shrivelling.

Bitten or Perforated Leaves.

In herbaceous plants, as also in trees in different localities, the leaves are often strongly perforated as if some animal had eaten away the tissue between the veins, without, however, finding any animal on whom the blame may be laid. Since the injury increases in intensity with time, observers are more eager to find the cause. In extreme cases the injury is of such extent that the leaves appear like many paned windows, since only the network of veins remains together with a slight margin of leaf parenchyma. Such leaves are often bent and twisted but do not die prematurely. The shoots themselves show no disease and frequently new sprouts with normal foliage develop in the axils of these perforated leaves.

The most extreme case which I have had opportunity to observe was found in potatoes. The shoots of the plants at the beginning of July bore only perforated leaves (see Fig. 72). Usually the lower leaves were perforated only in places, the upper ones were split longitudinally in the areas between the veins and frequently parts of the edge were also destroyed. The younger leaves often had a feathery appearance since the different leaflets consisted only of the veins with a very slender margin.

Between the perforations yellowish points were seen in the leaf-blade when held to the light. These proved to be the first stages of the process of suberization which ended with the perforation of the leaf. The formation

of cork took place in the way described in the preceding general section. It was proved, however, to be a secondary phenomenon. The disease first manifested itself in the pale green color of the mesophyll usually near the finely anastomosing veins. This appeared more frequently in the palisade than in the spongy parenchyma. In isolated cases, instead of becoming pale, the cell contents discolored to a brownish tone which was accompanied by the suberization of the walls. The epidermis, in its changes, followed the mesophyll groups and small dead tissue centers were produced which did not change any further.

In the group of cells forming the transparent places in the leaf because of the dissolution of the chlorophyll, an enlargement was seen on account

Fig. 72. Potato leaf perforated as a result of a morbid formation of cork.

of which the non-participating epidermis was pushed outward. A cork formation now set in among the enlarged mesophyll cells; then these places broke out. By the advance of these processes backward into the flesh of the leaf, the cork centers were depressed to complete perforation. This can be understood easily since young leaves are affected. In their growth, these stretch all the tissues; since the tissues containing cork cannot stretch with the other tissue, they must tear.

The process, therefore, is, in principle, that found on the stems of cacti.

In other plants also, which show perforations of the leaves, the impoverishment and enlargement of different cell groups may be recognized as the early stages and, on this account, naturally belong to the phenomena

which will later be described as intumescences. The causes will also be taken up more in detail then.

In the production of the perforations, individual nutrition plays a prominent part; for, in the same place of growth, specimens which seem almost eaten up, may be found near plants which remain untouched. At times, only isolated species suffer. Thus, for example, I found in groups of different species of maple only one single vigorously growing variety which was diseased, among other kinds developing normally.

Formation of Cork on Fruits.

The brown, dull, not infrequently scaley spots or lines on the smooth outer surface of apples and pears, the so-called *rusty tracery* is well-known. Some varieties show the phenomenon every year, so that it has been included in the general description of the species. They are formations of cork, which, as a rule, arise from the stomata. In some years the process becomes abnormal in its appearance, so that not only "the varieties with rust spots" have a partial or entire cork-colored surface, but also the fruits of varieties usually remaining smooth-skinned are affected.

Fig. 73. Grapes with cork warts (W) on the fruit stem.

Injuries to the epidermis when the fruit first swells are the cause of this phenomenon. In cases already known to me (apples, pears, plums, grapes), it could be proved that a light late frost had split the cuticle covering of the young fruit in innumerable small tears. Under these microscopically small splits, the fruit at once formed cork layers. In places the epidermal cells die and remain together with the first formed cork layers as scales on the rather dull, leather colored surface of the fruit.

Whenever the corked places form a contiguous surface, the fruit in development does not swell uniformly, with the result that huge splits show on the fruit itself. The spores of Monilia especially enter these places and mummify the fruit.

But these phenomena, in the strictest sense, do not belong here. They are connected with an excess of moisture only in so far as the splitting occurs the more easily, the more quickly the swelling of the fruit takes place with continued moisture.

On the other hand, I would like to consider the appearance of cork warts on the stems of grapes as a process which becomes noticeable only in moist air. In Fig. 73 we see two grapes, the stems of which exhibit a browned rough surface due to the appearance of many cork-colored, closely distributed warts. The phenomenon occurs before the grapes have reached their normal size.

The warts are developed most abundantly at the place where the grapes join the stem: large branches of the clusters usually remain smooth and, as a rule, only some grapes show the disease. This is unimportant in continued dry weather, but with humidity makes for a development of parasites. If then a sharp dry period follows, some of the very warted stems shrivel and the grapes as well.

Fig. 74 shows a cross-section through a warty grape stem which exhibits the usual axillary structure and has some strikingly broad medullary rays (*ms*) which divide the wood ring (*h*). In the bark we notice a regular distribution of the hard bast groups (*b*) and in front of them the sieve elements (*s*) with often thickly swollen walls. At *o* is indicated one of the abundant crystals of calcium oxalate. These occur at times as small glands, at times as raphides. The different stages of the formation of these corky warts are shown at *W*. The wart-like excrescences, which resemble lenticels, are produced by the radial enlargement of some of the parenchyma cells lying immediately beneath the epidermis or somewhat deeper; and the consequent outpushing of the outer skin. By an increase of this process, which does not preclude the dividing of the elongated cells, an accumulation of tissue is produced with a corky covering which finally becomes brown and splits. By the increase of the bark parenchyma and the dying of the outermost brown corked elements the large warts are produced, the peripheral cell layers of which are pushed out from each other in a saucer-shaped form. A distinct cork cambium is formed connected with the dying bark of the outermost layers. This constantly extends deeper into the bark of the stem. If the weather continues to be cloudy, warm and damp, or if the grapes are too much hidden under the foliage, the conditions are ideal for the development of fungi among which may be noticed first of all *Botrytis cinerea*.

Fig. 74. Cross-section through the warty fruit stem of a grape. (Orig.)

The phenomenon is especially frequent in greenhouses, and here the close, moist atmosphere must be improved by ventilation and heat must be provided at the same time. If the warty grape stems are found out of doors, some of the foliage above the bunches of grapes must be removed and, after each rain, the water retained by the foliage carefully shaken off.

As a phenomenon related to cork excrescences, I once observed wings on young grape leaves. These appeared between the larger side veins on the leaf blade and were opposite each other like lips. These outgrowths (emergences) were a development of the blade usually forming over a vascular bundle.

The *chagrinisation (granulation) of the rose stem* should be cited here in addition. As is well known, standard roses are laid flat through the winter and covered with brush or earth. At times in the spring when these are raised from the soil, the young bark stems, which should be smooth, are often found covered with small warts, many having, as a rule, a pale or brownish-red periphery. The warts are outgrowths of the lenticel. These begin below the stomata and force the guard cells apart. Mycelia may be proved to be present if the periphery is discolored.

Yellow Spots (Aurigo).

At times the leaves of monocotyledons, more than those of dicotyledons, are covered with yellow or reddish brown specks. This speckled condition begins at the tip. The specks usually shade through a pale green zone into the otherwise normally green leaf. Their number may be increased, since, as the disease progresses, small new specks are formed between the older ones. At times the tissues affected in the discoloration are forced out, which shows a clear transition to real intumescences[1].

This yellow spotting occurs especially in greenhouse and house plants, and among these, we find it most frequently in Dracaenae, palms and varieties of Pandanus.

To illustrate the formation of these specks and show how, under certain circumstances, they increase until the leaf is perforated, I will cite some observations on *Pandanus javanicus.*

The spots always begin in the part of a mesophyll lying between two veins. Toward the upper side of the leaf these cells resemble the palisade parenchyma, on the under side, spongy parenchyma, but in the centre they are very thin walled, approximately isodiametric, somewhat hexagonal, filled with a colorless watery content.

From the innermost colorless tissue groups, the peripheral cells, i. e., those bordering on the mesophyll, containing chlorophyll, begin to stretch excessively toward the side of the least resistance, viz., toward the centre, whereby they frequently compress the central cells. Frequently the elongation takes place only in the cells arranged directly upward and downward, but not in the lateral ones of the thin-walled group, and a peculiar arrangement is thus produced. The central part of the tissue then consists of empty cells arranged radially, elongated like pouches, which often have become thick-walled by swelling, later browning and turning to cork. With increasing intensity, the spongy parenchyma is involved in this process of elongation with the dissolving of its chlorophyll body; its contents disinte-

[1] Vol. 9, Part 5.

grate into a brown granular substance, and in this the yellow coloration becomes more intensive. The upper surface of the leaf is often raised like a wart when the tissue, rich in chlorophyll, is drawn into the abnormal process of elongation.

Frequently the progress of the disease is stopped when the elongated cells become cork, then there are only yellow spots, recognizable when immature, indeed, only when the light falls through them. The whole centre of the disease may then be separated from the healthy tissue by a zone of actual cork cells. As the disease advances in severity even the cells of the vascular bundle sheath may be affected and show the characteristic elongation, browning and swelling until finally the elongating mesophyll cells rupture the epidermis above them. The processes already described under the phenomenon of perforation now follow. Diseases due to fungi and seemingly similar in outward appearances may easily be distinguished in Pandanus, since in them there is no elongation of the cells. In *Dracaena rubra* and Draco, the disease at times only disintegrates the chlorophyll of the inner cell groups; here membranes are often seen with *bead-like swollen places* extending into the inner part of the cell. In studying *Dracaena indivisa,* I observed an abundant formation of sugar in those tissues in which the chlorophyll had dissolved. This sugar did not occur in healthy tissues and disappeared from the diseased spots as soon as the walls began to turn brown and develop cork.

Hence this yellow spotted condition seems in many cases to be an initial stage of real intumescence, in others, as in the Dracaena, it is usually a diseased condition without any sequelae and the temporary increase of sugar and the bead-like swellings of the walls point to causes which are similarly affective in the over-elongation of the cells. In practical treatment, one should realize that the plants exhibiting aurigo suffer from a supply of water which they cannot assimilate. The amount of water destroying the equilibrium need not be greater than that normally supplied, but, being given during the dormant period, the plant cannot utilize it and the external conditions are not such as could stimulate this absorption. The spots occur with great frequency in the autumn and winter when the plants are brought into a warm place. They then have sufficient heat, water and mineral nutrient substances, but the light is deficient. Hence the one-sided stimulus must be removed and the plant put in a cooler, dryer place where there is as much light as possible.

Intumescences.

The knot-like or pustule-like distensions of the tissue usually occurring in groups and which I have considered as "Intumescentia" have not been sufficiently studied by practical pathologists. They are most abundant in leaves but are not rare on the stems. However, as yet, the observation of intumescences on blossoms and fruits has been limited.

The consideration of a specific case gives the best information as to the development of such structures, the value of which lies in their symptomatic

significance. In January, 1879, I observed specimens of *Cassia tomentosa* in a hothouse. I found the edges of leaflets on young shoots were curled under. This curling seemed to be due to the increased growth of the upper side, which showed a pustule-like convexity. When these convexities were fewer and located along the mid-rib, the leaflet was less curled. If they were scattered abundantly and uniformly over the whole surface, the leaf seemed almost blistered. This cannot be said to be actually blistered, however, because the convexity of the upper side corresponds to no equally great concavity of the underside.

The swelling is conical, having, at first, the same color and dull upper surface as the rest of the leaf. Later the tip of the cone becomes light colored, more rigid and shiny. Still later the tip becomes yellow, broadens and finally ruptures (Fig. 75, *ze*), if the whole leaflet has not already turned

Fig. 75. Leaf intumescences in **Cassia tomentosa.** (Orig.)

yellow, the swelling now seems depressed in the centre, funnel-like, and turns brown.

The phenomenon is due to a sporadic tube-like outgrowth of the upper palisade parenchyma (*p*). The inner side contains many chloroplasts closely packed together and, toward the spongy parenchyma, is provided with slender, slit-like intercellular spaces filled with air.

With the appearance of swelling, the chloroplasts begin to disappear from the tip of the cell backward, a few of the cells become elongated; gradually the surrounding tissues are involved. More and more chlorophyll is dissolved as the elongation advances, so that finally the palisade cells, which have become tube-like, seem almost entirely colorless or are provided with a few small yellowish grains scattered throughout the whole cell lumen. With this elongation of the cells forcing up the epidermis there is a slight increase in width, which presses the cells very close against one another laterally, with only small intercellular spaces in the spongy parenchyma. As

soon as this pressure has ruptured the epidermis (e) at the highest point of the excrescence (ze) the ends of the palisade parenchyma, which are now freed, swell up like clubs (kp) and, turning brown, thicken their walls more or less farther back. The epidermal cells which are ruptured, and others in the same region, turn brown and partially collapse.

The same swelling can also occur on the side of the leaf. In this case, the spongy parenchyma cells lying directly beneath the epidermis, covered with hairs (h) and otherwise usually isodiametric, become long and cylindrical.

In various epidermal cells of the upper as well as the lower side of the leaf and in many of the parenchyma cells which have grown out like tubes, glycerin draws together in individual large glucose drops or many small ones.

I found similar leaf distensions in *Acacia longifolia* and *A. microbotrya* leaves specked with yellow and also on those normally green.

Myrmecodia echinata is an example of the general appearance of intumescences with cork leaves. The leaves of this plant usually develop intumescences on the lower side, while the cork excrescences predominate on the upper side. In Fig 76 we perceive that actually both of the parencyma layers lying next to the epidermis participate in the formation of the delicate gland-like outgrowth of the tissue. The epidermis (c) (its stomata are unchanged) is raised up and ruptured where it joins the normal tissue. Strange to say, however, it appears to be still unbrowned and turgescent, i. e., still completely and sufficiently nourished like the tube-like mesophyll cells (a). I found that the excrescences had dried up and had been cut off from the healthy parenchyma by the formation of the layer of flattened cork cells at their base (b) only when the leaf was well advanced in age.

Fig. 76. Piece of a leaf of Myrmecodia echinata with a cork wart breaking out on the upper side and gland-like intumescence on the under side. (Orig.)

The partially blister-like, partially wart-like cork excrescences are most frequently found without intumescences. They are distributed irregularly over the whole leaf surface as rusty, sometimes silvery shining specks; the region of the mid-rib is most affected.

The cork forms first within the epidermal cells, advancing thence into the mesophyll, attacking at first two adjoining layers of the hypoderm,

formed of four or five rows of colorless cells with very wide lumina but poor in contents (*d*). The underlying palisade parenchyma, extending into the hypoderm in the conical-like buttresses (*e*) is usually not affected, but, like the spongy parenchyma, poor in chlorophyll, often exhibits strongly refractive, often green colored drops in its cells where the cork is formed.

Often such corky masses very greatly resemble certain fungous discases as I have had opportunity to observe in *Pelargonium zonale.*

The under sides of the leaves were covered with white cystopus-like masses, isolated or united into large groups. These were hemispherical cork excrescences, later separated from one another like fans and filled with air. They began with an enlargement of the spongy parenchyma, whereby all the intercellular spaces were filled up. The epidermis, as a rule, remained unchanged while the mesophyll cells adjoining it were elongated perpendicularly and were divided by cork walls, with a gradual loss of chlorophyll. The cork cells partially lost their parallel arrangement because of an irregular increase and were much distended until the epidermis ruptured. The epidermis, however, manifested its restraining influence by pressing upon the cork cells, so that their walls seemed crumpled. The process of elongation and suberization extended deeper and deeper into the mesophyll until at times the excrescence was four times as thick as the leaf. A brown, twisted mycelium (possibly a Cladisporium) grew into the stomata and later into the wound of the rupturing cork excrescence.

Grapes are especially susceptible to intumescences and especially those plants taken from greenhouses into the open for early forcing. In addition to the excrescences on the leaves, little knots were formed on the stem of the grapes, and, since the structure of these differed from the warts already described, they may be considered here more thoroughly.

Fig. 77 is a cross-section through such a knot. The vascular bundles, forming the wood-ring of the stem, are indicated by *h*, the pith by *m*; the hard bast by *hb*; the abnormal change in the bark parenchyma extends to this point. This change is characterized by a distension of the parenchyma lying underneath the collenchyma-like elements and an ultimate elongation, the cells of which have subsequently divided. Because of this over elongation the collenchyma (*c*) is pressed together and, without previously having participated in the elongation, dies together with the epidermis. The normal epidermis may be recognized at *e*; *k* indicates the cork zone formed on the boundary of the dying tissue. The latter may not always be found, however. Often the dying tissue passes over imperceptibly into the very thin-walled, still living tissue which shows slight cork formation at the place of transition. *cg* indicates the normal collenchyma, occurring in groups and not in connected rings. The division and over-elongation of the bark parenchyma and the absence of cork excrescences distinguish these knot-like intumescences from the cork warts which, in an immature stage, resemble them greatly.

The intumescences on grape leaves have on the under side the form of gland-like elevations which often coalesce and are indicated on the upper leaf surface by yellowish and at times somewhat raised places. They are produced by tube-like outgrowths of the spongy parenchyma lying under the epidermis; the cells of this spongy parenchyma are poor in solid contents and closely pressed against one another by the distension. With their increasing over-elongation, the epidermis is browned and ruptured.

In the beginning only the cells lying directly beneath the epidermis are affected, but usually, after the distension begins, the cell layer next below is attacked and it is usually this which later is most elongated and its cells not infrequently divided by cross walls. The cells forming the centre of the swelling are the longest and most slender and stand exactly perpendicular to the outer surface of the leaf, while those laterally adjacent are arranged

Fig. 77. Part of a knot-like intumescence on the stem of a grape. (Orig.)

slantingly like a fan, decreasing in length, increasing in width. The presence of starch could not be proved. In the most extreme cases observed, all the cells of the mesophyll, up to the palisade parenchyma of the upper side, take part in this elongation. I did not observe, however, that the palisade parenchyma had been attacked.

These intumescences are not infrequent in vineyards and cases may be found showing their cause most clearly. In the course of years material has come most abundantly to my hands. I quote from the report of the court gardener, Mr. Rose.

He had a grape house planted with 14 vines; of these, six were Black Hamburgs (Blauer Frankenthaler), one of these was planted where the hot water pipe entered. Therefore, the temperature was higher and the humidity very great.

This vine alone developed intumescences to such a degree that the under side of the leaves seemed almost felty. A Royal Muscardine vine

was planted on the opposite side of the greenhouse. The foliage of these two plants became intertwined as they grew into the upper part of the house. The Royal Muscardine plant had no trace of disease.

These instances show how differently varieties behave in the same environment, and how individual diseases in the same variety may be explained.

In regard to the different behavior of different vines, reference should be made to a study by Fr. Muth[1], who observed the production of intumescences after spraying the leaves with copper compounds, while, for example, the early red Veltliner and Muscat St. Lauret show no swelling. Morillon panaché, Madeleine Angevine and the Blue Ox-eye were very greatly affected.

In another similar case, Noack[2] found that the disease decreased when water was withheld.

The occurrence above described does not correspond with the phenomena found on *Ampelopsis hederacea*[3]. In this plant Tomaschek found ***bead-like structures*** on young branches, petioles and leaf veins, and especially on the outer side of the side leaves. The beads were very small when the illumination was insufficient and dried up in the autumn. They were formed below the stomata even in the very young parts, since the cells surrounding one cavity grew down into it and forced up the epidermis by an increase in size. In the autumn and winter true lenticels with a cork formation were found, instead of these outgrowths.

In addition to the instances already described and those to be mentioned further on of disease manifesting itself on greenhouse plants, I will now report on the behavior of one of the Gramineae.

On the island Rügen, among vigorously growing oats, plants were found showing abnormal growth. A cross-section of the lowest node, covered with dirt, is illustrated in Fig. 78. The centre of the node exhibits the well known irregular course of the vascular bundles (*g*) and the primordia of a root (*w*) ready to break through the distended bark of the node. In this bark covering *r* indicates the normally formed part, while at *r'* the subepidermal parenchyma cells are already beginning to elongate radially. The excessive elongation increases at *s* to a decidedly tube-like character and affects all layers of the bark near the root just coming through. This distends the epidermis very greatly, and, as its cells do not take part in the process of elongation, it finally begins to separate in different places (*c*). The leaf blade at *z* shows an external injury from grazing cattle which extends deep into the node. The tissue is considerably browned, the vessels, as far as the middle of the node, are partially filled with gum. The

1 Muth, Fr. Über die Beschädigung der Rebenblätter durch Kupferspritzmittel. Mittel. d. Deutsch. Weinbau-Vereins 1906.

2 Noack, Fr., Eine Treibhauskrankheit der Weinrebe. Gartenflora 1901, p. 619.

3 Tomaschek, Über pathogene Emergenzen auf **Ampelopsis hederacea.** Österr. Bot. Zeit. 1879, p. 87.

facts warrant considering this injury the exciting agent in the formation of intumescences. Other adjacent blades which have not been similarly injured, do not develop the excrescences. The assumption can be very easily made that, given an abundant supply of water and nutritive substances, the turgescence in the stem would be great, while the evaporation from the node covered with soil would be slight and an injury from grazing cattle which would remove part of the tissue, would so increase the turgor that intumescences would be formed.

I had already observed similar correlation phenomena in the action of copper sprays on potato leaves[1]. In vigorously growing varieties a number of leaves were found injured by the spray; near the dead spots in the tissue, the intumescences later appeared. Still other causes may have similar

Fig. 78. Intumescence on the lower node of an oat plant.

results, since small warts have been observed on potato leaves when the copper solution had not been used[2]. Von Schrenck[3] has reported more recent results in this connection. A few days after cabbage plants in greenhouses had been sprayed with copper ammonium carbonate, pale knots, gradually becoming white, developed on the under side of the leaves. They proved to be intumescences. Unsprayed plants in the same house showed no eruptions. Spraying with weak solutions of copper chlorid, copper acetate, copper nitrate and copper sulphate did cause some distensions. Von Schrenk, however, considered these intumescences a reaction of the leaf tissue to the chemical stimulus of the poisons, not correlative phenomena.

[1] Sorauer, P., Einige Beobachtungen bei der Anwendung von Kupfermitteln gegen die Kartoffelkrankheit. Zeitschr. f. Pflanzenkrankh. 1893, p. 32.

[2] Masters, Leaves of potatoes with warts. Gard. Chron. 1878, I, p. 802.

[3] Schrenk, H. v., Intumescences formed as a result of chemical stimulation. Sixteenth ann. report Missouri Bot. Gard. May, 1905.

Here belongs the case which Haberlandt[1] describes in a Liane, Conocephalus. He describes the formation of compensatory hydathodes, after the normal organs of the leaves have been poisoned. The extremely abundant nocturnal transpiration takes place at the base of the shallow depressions on the upper side of the leaf by means of sharply differentiated, epithemial hydathodes with water pores always lying over the juncture of vascular bundles. Where these organs had been poisoned by painting the leaf with a 0.5 per cent. alcoholic sublimate solution, small knots were

Fig. 79. Stem of **Lavatera trimestris** —with intumescence. (Orig.)

Fig. 80. Branch of **Acacia pendulata**—with intumescence. (Orig.)

Fig. 81. Magnified section of Fig. 80. (Orig.)

formed above the vascular bundles. Each morning large drops of water were found on these places. These knots, which had assumed the function of the dead hydathodes, seemed to be composed of long, pouch-like cells, in the lower part divided by cross walls adjoining one another (without intercellular spaces). The club-like swollen ends separate from one another like a brush. They have been produced by the elongation of the conductive parenchyma cells and often of the palisade cells and have broken through the epidermis.

[1] Haberlandt in "Festchrift für Schwendener," cit. in Naturwiss. Wochenschr. 1899, p. 287.

Fig. 79 shows the habit of growth of a piece of *Lavatera trimestris* stem with excrescences due to cell elongation. Fig. 80 shows the ruptured bark of *Acacia pendula,* while Fig. 81 shows the same much more clearly because of its magnification.

In *Malope grandiflora* and *Lavatera trimestris,* stems and branches were found bearing many long calluses on the side exposed to the sun. These were caused by considerable longitudinal and radial stretching of the bark and wood cells. If the callus is still young, the process usually sets in by a radial and still more marked tangential stretching, at the level of the primary hard bast bundles of the parenchyma cells containing chlorophyll and lying between two bundles: with this increase they are pushed outward

Fig. 82. Cross-section through a year old branch of Acacia pendula with intumescence. (1-433).) (Orig.)

like a bow. The mechanical ring appears to be broken because the bast bundles are pressed far apart and the collenchyma layers less developed. In large intumescences the broken places apparently extend deeper since the wood also changes its prosenchymatous elements and the cells of its medullary rays into a wide meshed parenchyma.

Fig. 82 throws sufficient light on the processes concerned in the formation of the moss-like collection of intumescences in *Acacia pendula; m* indicates the pith; *h* the woodring; *c* the cambium; *b* the hard bast groups; *e* the epidermis; *s* the beginnings of elongation within the primary bark; *w* the bark parenchyma cells which have become tube-like and ascend in spirally parallel rows and, after breaking through the epidermis at *w,* separate from one another like sheaves.

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1) Sorauer, P., Über Intumescenzen. Ber. d. Deutsch. Bot. Ges. 1899, Bd. XVII, S. 468.

When the intumescence is highly developed, the over-elongation extends backward to the secondary bark, stretching the cells of the phloem rays (*q*). In fact, cases occur in which the woodring seems stimulated in those layers last formed because the outermost cambial layers are constructed of parenchyma wood. As on the various kinds of Eucalyptus, the intumescences occur most frequently on the side of the branch turned toward the light, and often only then. After the explanation given these cases, a more thorough discussion is needed here.

Fig. 83. Blossoms of Cymbidium Lowi with gland-like intumescence (a) on the tops of the perianth. (Orig.)

Intumescences occur most rarely on blossom organs. I observed one such case in *Cymbidium Lowi.* The blossoms, normally large and otherwise well-developed, exhibited on the under side of the perianth, quince yellow or yellowish green, hemispherical bosses (Fig. 83*a*); exactly the same structures could be found also on the ovaries. In an immature stage they had a smooth upper surface, later they cracked open in the apical region and became depressed like a funnel. In the older knots, the depression advanced to complete *perforation of the perianth tip*. For this reason the blossoms were unsalable. In Fig. 84, it may be seen that the cell layer found beneath

the epidermis (*e*) of the under side of one part of the perianth has developed erect, club-like tubes, at first bent toward one another like lopped trunks (*s*), which first had been held together by the brown-walled, swollen epidermis not affected by the stretching. After the epidermis had ruptured, the tubes, which were rather thick walled, deep brown and had lost their contents, separated from one another like sheaves. The process of the over-elongation gradually attacks the deeper and deeper lying parts of the cell and finally advances even directly to the upper epidermis (*w*). At this time the epidermis ruptures and the tips of the perianth tip[1] become perforated.

The first stages of the intumescences have been studied in the ovaries. The first symptoms are a localized change in the epidermal cells, the walls of which are yel-

Fig. 84. Cross-section through an intumescence on the perianth of Cymbidium Lowi. Upper figure, young stage; lower figure, mature condition. (Orig.)

O upper side, *U* under side, *e* epidermis, *s* (upper figure) beginning of elongation of the sub-epidermal cells, *s* (lower figure) the rupturing of the club-like over-elongated cells, *g* vascular bundled, *w* avanced condition of perforation

the tissue is perfectly colorless, more closely pressed together and filled more abundantly with protoplasm and oily looking drops. In some of these places a radial stretching has already taken place, which increases up to a diagonal inclination and cross-division. The process gradually extends to the surrounding cells, especially to those lying directly beneath the epidermis. The elongating layer becomes strikingly thick-walled and turns coffee brown, while the collapsing, swollen epidermis forms a light yellowish brown cap. The discoloration is accompanied by a process of suberization, and to this probably may be ascribed the fact that the cells, becoming brittle in the still

[1] Sorauer, P., Intumescences an Blüten Ber. d. Deutsch. Bot. Ges. 1901. Vol. 19, p. 115.

incompletely developed organs affected during their elongation, rupture and crumble. This is the beginning of the funnel-like depression at the tip of the intumescence.

Among fruit intumescences, I have most frequently observed the unripe pods of beans and peas and noticed that many varieties of fungi infested the pods. The fruits, especially when near the surface of the soil, seemed closely covered with warts and awakened the suspicion of a marked fungous infection, as may be seen in the pea-pod shown in Fig. 85.

In cross-section, it may be seen in different places, which still seem smooth to the naked eye, that some epidermal cells have already begun to elongate. These often lie directly beside the stomata, but without the coöperation of the stomata in producing intumescences. Gradually the parenchyma cells lying below become elongated. The elongated elements are often divided by cross-walls and form warts. However, these are first formed of rows of cells arranged like columns. These warts grow to a height of one millimeter; later they become brown from the dying of the peripheral layers and, after the covering splits, the rows of cells spread out like a sheaf.

Fig. 85. Pea-pods with gland-like raised outer surface. (Orig.)

Fig. 86 shows the greatest development. The normal wall of the pod is shown at *fr;* *e* indicates the epidermis; *p* layers of the thick-walled partially intersecting elements of the inner parchment-like fruit membrane. In the centre of the outgrowth (*w*) the elongated columnarly arranged parenchyma cells, separating toward the outside, irregularly like a fan, are visible. The outermost peripheral zones, shaded in the drawing (*z*, *z*), indicate the moribund tissue. The walls of these collapsed parenchyma groups, often shrinking together in curling tips, seem yellow to brown and give the warts an earthy color. From the repeated splitting of the intumescences, which are often so close to one another that only a few normal epidermal cells separate them, the whole wall of the pod obtains in places a mossy outer surface.

The parchment-like inner wall of the pod forms intumescences; indeed this is more frequently the case than on the outer wall. In some kinds of peas, with very pithy pods, white tissue felts resembling species of mold may be found almost every year on the firm, smooth inner surface. In one case in the intumescence tissue, I found numerous oospores which presumably had belonged to *Peronospora Viciae*

From the examples already cited it is evident that the intumescences may occur on all aërial organs of plants. They form one link in a chain of phenomena which in part commonly occur together and in part, in fact, overlap. We have described the simplest disturbances as "Aurigo;" they are characterized by the impoverishment of some tissue groups in the interior of the leaf with a destruction of the chlorophyll apparatus, usually with the formation of carotin. As the chlorophyll disappears the cells are apt to become distended. They fill the intercellular spaces, thus exercising pressure on the surroundings; they finally die as the cell walls become suberized. Such nests of over-elongated cells are also termed *"internal intumescences."* In real intumescences the processes of impoverishment and cell elongation begin in the peripheral layers of the organs and in fact usually in the sub-epidermal cell layers, more rarely in the epidermis itself. The process of over-elongation is less impeded here and frequently advances into the more deeply lying tissue layers, so that we find cases of intumescences beginning on the under side of the leaf and gradually including the whole mesophyll as far as the upper epidermis. If the formation of cork sets in in the intumescence tissue, we find wart-like or pitted cork centres which can lead to the complete perforation of the leaf.

Fig. 86. Cross-section through the outer surface of pea-pods with intumescences. (Orig.)

On the trunk the intumescence manifests itself in the hypertrophy of the bark parenchyma which, in isolated enclosed centres, breaks out from the bark in the form of warts with a smooth or repeatedly split outer surface. If the processes of over-elongation are not restricted to small isolated centres but attack the parenchymatous tissue in large, connected surfaces, all the organs rupture, causing the condition which we have called "dropsy."

Although the phenomena described here are related structurally, we have treated them separately because different conditions are the dominating causes of different outbreaks. Many investigations have shown that an atmosphere heavily ladened with moisture is a decisive influence in causing intumescences.

References to my work and that of other older investigators may be found in the bibliography of Küster's[1] "Pathological Anatomy." I will cite

[1] Küster, Ernst, Pathologische Anatomie. Jena 1903. Gustav Fischer.

here a few especially pertinent observations. Some of these consider the question of light on the production of an intumescence. In this connection Atkinson[1] explains that increased turgescence in leaves will be produced by repressed transpiration if the greenhouses are poorly lighted. Actually, in many cases, I found intumescences in the autumn and winter, because of cool, cloudy weather, if the greenhouses had to be heated after the plants had been brought in from outside. Trotter[2] states directly that half darkness favors the formation of intumescences. Steiner[3] also made the same observation, but stated that they will form only in the first days of darkness, so that one may conjecture an after effect of the former activity of the light. This author observed also in Ruellia and Aphelandra, that the plants with equal atmospheric humidity only formed intumescences for a few weeks and therefore had adjusted themselves to the high degree of moisture. That the *abrupt transition* from dry to moist air is actually the decisive factor is shown by the renewed formation of intumescences, when the plants, after having become adjusted to a dry atmosphere for three weeks are brought again into moist air.

Steiner found that no intumescences are produced under water, as did Küster[4] on poplar leaves which he had left floating on water or nutrient solutions and in darkness as well as in light. Only when the illumination was too great, this process was suppressed, probably as a result of increased transpiration. In contrast to this, Viala and Pacottet[5], in describing intumescences on grape leaves in greenhouses, said they had determined by direct experiment that intumescences are produced by the action of the light in a moist atmosphere. They are produced only directly under glass. The Missouri Botanical Garden makes a similar report.

The most thorough experimental studies are Miss Dale's[6]. She observed with *Hibiscus vitifolius,* that the yellow and red rays are especially effective in producing intumescences. Her experiments with potatoes are especially instructive in regard to the action of sudden changes in the vegetative conditions. The plants were grown in a cold section of a greenhouse and then set in a warm house at a temperature of about 21°C., under a brightly illuminated bell-glass. After 48 hours, the stem and the upper side of almost all the leaves were covered with masses of pale green raised spots. If the plants were then brought into dry air, the blisters shrivelled

1 Atkinson, G. F., Oedema of the tomato. Bull. Cornell Agric. Exp. Station 1893, No. 53.

2 Trotter, A., Intumescences fogliari di **Ipomea Batatas.** Annali di Botanica 1904, No. 1.

3 Steiner, Rudolf, Über Intumescenzen bei **Ruelli formosa** und **Aphelandra Porteana.** Ber. d. Deutsch. Bot. Ges. 1905, Vol. 23, p. 105.

4 Küster, E., Über experimentell erzeugte Intumescenzen. Ber. der Deutsch. Bot. Ges. 1903, Vol. 21, p. 452.

5 Viala et Pacottet, Sur les verrues des feuilles de la vigne. Compt. rend. Acad. d. sciences 1904, No. 138.

6 Dale, E., Investigations on the abnormal outgrowths or intumescences on **Hibiscus vitifolius.** Phil. Trans. R. Soc. of London. ser. B. 1901, Vol. 194.— Dale, E., Further experiments and histological investigations on intumescences, with some observations on nuclear division in pathological tissues. Phil. Trans. R. Soc. of London 1906, ser. B. Vol. 198.

up to black spots or perforated the leaves. If some leaves fell, when the the plants were kept longer under the moist conditions, a great cushion of intumescences was produced on the leaf scar which displayed similarity to the wound callus. Older plants under similar conditions did not develop intumescences as quickly, nor as abundantly, while very old leaves developed none. Pieces of leaves, laid in moist cotton, after possibly two days, were thickly covered with eruptions. Quickly growing plants react most easily to the stimulus of a sudden change in the amount of moisture.

These observations support our theory that the formation of intumescences is the reaction of the organ to a stimulus due to a sudden increase of atmospheric moisture. Only the immature organ reacts. If older leaves, as we observed, for example, with *Solanum Warscewiczii*, respond with a formation of intumescences after having been brought from the open air into a damp greenhouse, these are exceptional cases of a special excitability of the species. Such cases occur in various plant genera.

My results differ from those of other investigators, since I always found that intumescences invariably developed as the result of an arrested assimilation due to an excess or deficiency of light. It always manifests itself, however, in the scanty formation of solid reserve substances, usually, in fact, those already formed become dissolved. In accord with Miss Dale's assumption, the variation in assimilation may be connected with the increase of the oxalic acid content in the cells showing in the abnormal increase in turgor. In the same way, experiments with young leaves and pieces of leaves show how the root pressure may be eliminated.

Different combinations of the vegetative factors may give rise to that deficient assimilation which shows itself in the formation of intumescences. In the greater number of cases falling under my observation, I find the cause to be an increase of heat and moisture given to a plant naturally dormant, or being forced to arrest its assimilation from external conditions. The following action throws light on inhibitory regulations.

The Tubercle Disease of the Rubber Plant.

On the under side of the leaves are found numerous abundant, very small, gland or tubercle-like, hemispherical swellings. These are produced by the pouch-like elongation (Fig. 87, *int*) of the cells of the leaf, which, in a normal condition, have the form and arrangement shown at the side of the picture marked *m* and, therefore, are separated by larger or smaller intercellular spaces (*i*). The morbidly elongated tissue (*int*) on the under side of the leaf thus approaches the normal leaf palisade parenchyma (*p*) which is provided with a three-fold epidermis (*e*). Of these three layers, the outermost is small-celled and provided with a very thick layer of cuticle. The innermost cell layer of the epidermis displays more thin-walled, comparatively very broad cells (*w*), which form the so-called water-storage, protective layer. Isolated cells, enlarged like sacs, in this layer conceal

those peculiar grape-like clusters of cell substance incrusted with calcium (*c*) known as cystoliths.

The close structure of the upper epidermis of the leaf must prevent the passage of air, while the lower epidermis is well fitted for this purpose. The spongy parenchyma shows large intercellular spaces (*i*), the enclosed air in which can pass out through the air chambers under the stomata (*a*) and the stomata (*st*) to the outside, making room for the freshly entering outer air. The conduction of water takes place through the leaf veins, one of which is seen in section at *g* and shows at *r* the large ducts. The course

Fig. 87. Cross-section through a leaf tubercle of the rubber tree (Orig.)

of organized building substances, produced in the leaf and flowing down toward the trunk, is shown at *sch*, the sheath of the vascular bundle; *k* indicates the place at which the cells begin to enlarge because of an excessively increased turgor, thus filling the intercellular spaces and forming, therefore, first of all, "internal intumescences." The excessive water content manifests itself still more in the peripheral tissue, since, exposed only to the pressure of the epidermis, its cells elongate into tubes and, together with the epidermis, can be pushed outward (*int*).

Actually, therefore, the tubercle disease of the rubber plant is a regular intumescence which belongs to the previous division. We have, however,

isolated this phenomenon of disease, because it has an essentially practical significance in the cultivation of Fiscus as a market plant.

The disease occurs less often in plants grown for sale than in home ornamental plants, where it may lead to a premature defoliation. My experiments prove that it is produced by giving excessive heat and water to plants when their growth has stopped and their transpiration lessened, thus stimulating them to renewed activity. I produced intumescences by keeping a rubber plant in a very hot room and giving it abundant water after it had made a vigorous summer growth and passed into the normal resting period, instead of the cooler, drier environment which it should naturally have had. Leaves fell immediately, while intumescences were formed on the younger ones. When the plant was put in a light, but cooler place, the leaves with the intumescences remained on the stem until the next summer, when the plant again grew normally if somewhat more weakly.

This kind of disease and its cure may be considered characteristic. The intumescences, therefore, are ***highly significant symptoms*** of abnormal turgidity in all plants. As soon as they show themselves, the plant must be put into a light, cooler environment and given a decreased water supply.

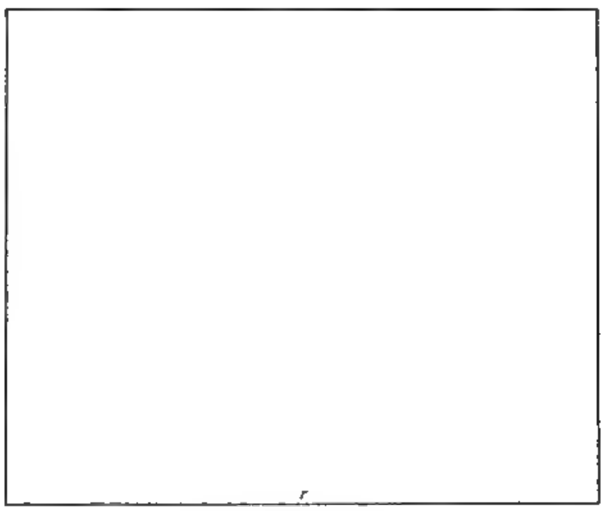

Fig. 88. Hyacinth bulb infected with the pustules of the skin disease. (Orig.)

s scales which have lost their gloss. *b* formation of pustles, *r* dried edge. *k* young bulb.

The Skin Diseases of Hyacinths.

This phenomenon (Fig. 88) has not been considered, although it occurs very frequently. Normally the outer scale leaves are smooth, firmly enclose the bulb, and usually extend up to its neck. In this disease they are short and die back from the dying edges. Often such hyacinth bulbs crack open and are thickly covered with dry leaves, especially near the place torn. On the still fleshy outer parts of the bulb, colonies of the blue-green mold (*Penicillium glaucum*) frequently occur.

The leaves standing isolated, or connected with one another, are flattened on the upper side and often many boil-like, swollen, yellow places appear. In the colored part also of normally dried bulb scales, they almost always show some mycelium. In cultures this is proved to belong to *Penicillium*. The tissue of such diseased places differs from that of normal

scales in its yellow, uncommonly brittle walls, breaking into sharply pointed pieces and in the wide lumina of the cells, while that of the healthy ones, with their somewhat swollen, thick, colorless walls, have sunk together until the lumen disappears. All traces of starch have disappeared from the yellow-walled tissue, which sometimes traverses the scale, is suberized, and pushed up by the subsequently produced cork cells and from the colorless surrounding tissue.

After the diseased, dry bulb scales have been removed, one notices that the still perfectly white, succulent scales, normally extending to the neck of the bulb, have begun to dry, beginning at the top. Here the tissue loses its natural smoothness and turgor, so that gradually the scale has a folded appearance, due to the collapse of the cells which lie between the more prominent vascular bundles. Besides this, the edge usually becomes yellowish. At the same time, on the deeper parts of the fleshy, white places in the scales, glistening from turgidity, appear small, longish, glassy, transparent, yellowish spots, protruding slightly above the upper surface. These

Fig. 89. Cross-section through a scale of a hyacinth infected with skin disease. (Orig.)

increase in a few days and almost at once become more noticeable because of the yellowish juicy edge. Then, however, the change advances more slowly, since the outpushing occurs only gradually more distinctly and its centre becomes whitish with a dry membrane and longitudinal folds; with increasing age, the centre becomes depressed and finally the scale seems perforated. When treated with sulfuric acid the upper lamellae, lying directly beneath the cuticle (Fig. 89 *l*) of the somewhat thickened epidermal cells, swell up markedly and *at times* mycelium may be found in them.

A cross-section through the diseased scale (Fig. 89) shows at *b* an older pustule and on the left of this a younger one. In the discolored epidermis, the walls are swollen and this process of swelling and suberization (*vk*) in the older leaves has already advanced through the whole thickness of the scale. Here the fleshy, starchless parenchyma, which at the beginning (*p*) was found to be still colorless and with a normal arrangement, has collapsed like cords and formed hardened places with irregular openings (*z*).

In the cells directly beneath the outpushed epidermis, there are no nuclei, while they are present in the next inner cells, but brown in color. In the epidermis, cork cells are produced, while the parenchyma lying beneath gives

the sugar reaction with the Trommer test. In this tissue, rich in sugar, the formation of cork advances and since the corked cells do not collapse, they rise gradually more and more above the other tissue of the bulb scales, the walls of which retain their cellulose reaction and collapse. Analyses give dry substance

	Healthy bulbs.		Diseased bulbs.	
In the outer scales	34.6 per cent.	51.82 per cent.	36.7 per cent.	55.43 per cent.
In the inner scales	22.4 "	33.50 "	32.6 "	40.16 "

Thus the diseased bulbs are richer in dry substance, which is not strange since the process of drying of the outermost scales has advanced rather further in them.

After the removal of all the brown colored scales, the sugar content (defined as grape sugar and reckoned on dry substance) is,

	Healthy bulbs.	Diseased bulbs.
In the outer scales...............	0.71 per cent.	0.82 per cent.
In the inner scales...............	1.23 "	1.66 "

That is, the bulbs are richer in sugar in the inner, younger scales than in the older ones, and when diseased both the inner and outer scales are richer in sugar than those in a healthy condition.

We thus obtain the same results as were found in the *ringing disease*. As a matter of fact, both diseases frequently occur simultaneously and these pustules, which may be termed intumescences, prove to be symptoms of a scantier ripening of the bulbs. This may be found even in very luxuriantly cracked specimens. It is self evident that *Penicillium* grows rapidly and frequently on such a medium. The skin disease therefore deserves great consideration as a symptom and indicates that bulbs should be grown in a *sandy* soil not too rich in humus nor too damp.

The Glassy Condition of Cacti.

A diseased condition was observed in various cacti and studied more closely by me with *Cereus nycticalus* Lk. This condition is characterized by the appearance of glassy places, later becoming black. In the more delicate Cereus varieties, a greater extension of this tissue change kills the part of the stem which lies above it. Death results either through a drying up of the blackened tissue, or with the assistance of bacteria, through the appearance of a pulpy condition, when the outer skin may be loosened by a slight pressure of the fingers. If the centre of disease is limited to one side of the stem, this may be healed, leaving deeper cup-like wounds.

The illustration on page 456, of the manner of growth, shows a piece of the stem of *Cereus nycticalus* blackened at the upper end and softened to a pulp. On this softened part, a strip of the outer skin has been loosened by a slanting pressure of the finger. At the base of the piece of the stem are found healed wounds which extend to the wood ring of the stem.

When examining badly diseased specimens, it is noticed that a number of glassy places occur like warts on the upper surface. The cross-section shows that while the outer part of the bark of this piece of stem is still dark green and normally constructed, the underlying bark layers lack chlorophyll and starch and have greatly enlarged cells which cause the warty excrescence. In contrast to the usual intumescences in which an elongation of the sub-epidermal layers causes the warty outgrowths which often rupture, I have termed the abnormal enlargement of the cell centres lying deeply depressed in the tissue, *"internal intumescences."* In this, these phenomena are related to the yellow-spotted condition described above. Here the first stages of the disease are found in centres of cells poor in content, browning and turning to cork in the midst of green tissue; only in cacti the stems are affected, while in Pandanus the changes are found in the leaf.

The cell aggregations, which usually increase only in one direction, collapse, while, especially in the bark of the cactus, the cells retaining thin, colored walls, are usually elongated into tubes and have a star-like arrangement. From these inner diseased tissue centres, the process of impoverishment and over-elongation of the bark parenchyma extends backward toward the wood-ring and laterally in the direction of the bark, constantly further around until a considerable part of the stem is browned or blackened. Finally the outermost cell layers are also attacked by the discoloration without the usual appearance of any over-elongation; rather, the stem appears as black as ink, even to the naked eye.

In the first stages of this disease, while the tissue still has a glassy appearance, the process of blackening occurs almost immediately after the sections are made, indicating that even then there are large amounts of tannic acid, which unite with the iron of the knife. Since, however, the discoloration follows when the plants have been injured with a horn knife, or with a platinum spatula, the presence of a sensitive substance must be assumed that rapidly discolors in the presence of the oxygen of the air. But guaiacum tinctures alone, or with hydrogen peroxide, do not give a blue coloration. With litmus paper the whole bark parenchyma gives a sharp acid reaction.

An accumulation of glucose may be considered as a factor which might begin the over-elongation of the cells; for, after treating the section with the Trommer sugar test, cuprous oxid is very freely precipitated in the glassy tissue as a whole, and this precipitate is scantier toward the healthy tissue. The proportion of starch content is the reverse. In the most diseased tissue, it is nil, while the healthier surrounding tissue displays starch abundantly. The proportion of calcium oxalate is peculiar; it occurs usually abundantly in the slime passages. In healthy green bark tissue, this calcium oxalate occurs chiefly as raphides, while in the diseased parts it is found usually in short octahedrons and at times in large cylinders. Probably varying amounts of the water of crystalization determine the form.

The upper figure in illustration 90 shows the process of healing. It is a cross-section through the branch with a depressed wound, which may be seen at the base of the picture, showing the habit of growth. *M* is the pith with its slime cells; *H*, normal old wood; *R*, bark. It is seen at the wound that the tissue atrophy originally included the whole bark (*R*). The wood cylinder (*H*), however, was not attacked. The edges of the bark wounds (*wr*) died and were separated by a full cork layer (*t*) from the healthy bark parenchyma at the sides. In the remaining part of the bark, a new growth in thickness had set in, which manifested itself by forming the primordia of new hard bast strands (*b'*). The old hard bast near the wound was diseased and found shut in by a cork envelope.

The whole tissue zone (*b'*-*b'*)had been formed anew subsequently, and indeed in those parts covered by the bark by means of a normal cambial activity, but at the wound itself by an increase of the youngest sapwood. For the wound destroyed the cambium, and accordingly the last formed cambial wood layer has started a renewed increase of cells and has formed callus-like tissue. The primordia of the vessels, which at the time of the deposition of the latest sap-wood had already become thick-walled, have, however, not taken part in the increase, but have been pushed outward passively by the newly formed callus. It is seen in this, that these primordia of the vessels (*g'*), which in the cross-section resemble the ducts (*g*) in the normal wood (*H*), now occur isolated in the callus tissue.

The healing process becomes more exactly recognizable in the lower anatomical figure which represents a piece of tissue from around the hole in the upper cross-section. *H* again represents the old wood with some vessels (*g*). Where the elements, represented with thick walls, cease, is seen the most depressed part of the wound. On this remain the youngest elements of the sap wood, which had increased in size and number after the phenomena of decay had ceased. The immature sap wood, already differentiated, became more porous and thin walled, and thus it happens that thin-walled vessels (*g'*) may be found again in a delicate parenchyma wood. All the tissue indicated by (*n*) has been newly formed, its production corresponding with the new formation of bark on peeled trunks. The new tissue, developed from the callus, already exhibits some differentiation. This differentiation indicates that the stem is about to form new bark where it was injured, for in the region directly in front of the thin-walled vessels (*g'*), we find the first parallel cell divisions indicating the formation of a new cambial zone. Besides these, the primordia of secondary hard bast (*b'*) may be recognized, to be sure, even in parenchymatous tissue with a plastic content but not containing chloroplasts, which later becomes normal bark.

This healing process, however, has only been observed when the plant had direct sunshine and fresh air in circulation. I have learned to recognize the disease as occurring in greenhouses and indeed in those where because they contain plants from warmer climates the air is enclosed and very moist. In one special case, the abundant ventilation in the greenhouse stopped the

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Fig. 90. At the right side of the figure, indicating the manner of growth, is a reduced piece of the stem of Cereus nycticalus, which, blackened and softened at the tip, shows a piece of the bark loosened by pressure of the fingers. On its lower part are found deep bowl-like wounds which have been healed. The upper drawing of the structure shows a cross-section of a bowl-like wound which is being healed. The lower drawing gives the new structures and tissue differentiations, which take place during the process of healing the wounds. (Orig.)

M pith. *H* wood. *R* bark, *g* normally placed ducts, *g'* displaced ducts, *b* groups of dead, hard bast of the outer bark, enclosed by bark, *b'* groups of young hard bast of the outer bark, *wr* dead edge of the wound of the older bark (*R*). The old tissue is separated from the healthy tissue by a layer of plate-like cork cells (*t*). *w* and *n* new bark differentiated from the wound callus.

disease, while in the following year, with the new planting of foliage plants and with accordingly increased humidity in the air, it reappeared to a great degree. For this reason, I would like to consider the phenomenon as a direct result of excessive humidity.

Methods for checking this are self evident. In one case, besides the increased supply of light and air, the addition of plaster to the soil has proved advantageous.

We have devoted considerable space to intumescences and related phenomena in order to point to their importance. Greenhouse plants are chiefly considered and repeated observations have shown that most numerous diseases may be traced to the act that the *natural dormant period of the plant was not considered* and the plants were stimulated to untimely and therefore abnormal growth, by a high degree of heat and moisture.

CHAPTER VI.

Fog.

In temperate climates, complaint is rarely heard of injuries from fog. In the mountains, vegetation has adjusted itself to the abundant precipitation and the attempt has been made so far as possible to overcome the delay of ripening grains and of drying the remaining vegetable produce by cultural regulations.

The so-called "fog holes" of the plains may also be "frost holes." These are distinguished by a vigorous lichen growth on the tree trunks.

In warm regions, fog becomes a more important factor, causing damage to plants, since it actually favors the development of saprophytic and parasitic fungi. We find the greatest number of complaints in regions where cotton is grown and exhaustive descriptions have been sent from Egypt. David[1] writes from the cotton experiment station at Zagazig that each October morning in lower Egypt, the soil is covered by heavy, thick vapors or low fogs. The first general result is that the bolls do not open because the carpophyles remain too tough. The foliage becomes covered with red spots, ascribed to the action of the sun on the dew drops, acting as lenses. The cotton fibres in the bolls decay and lose their value from the action of a black fungus. Besides cotton, *Hibiscus esculantus* and *H. cannabinus* also suffer; young maize plants as well. The irrigation with Nile water, its soaking through the land while the soil is fallow, makes it moist, dense and slimy or oozy. This physical characteristic is the chief factor which makes Egyptian fogs more disastrous than the English and mountain fogs.

The sensitiveness of cotton is due to its special soil and climate needs. These are very thoroughly described in Oppel's[2] special work. According to this, cotton as a low-land plant cannot endure a stony soil or any abrupt changes in temperature. In its time of growth, lasting six months, it requires 18° to 20°C. a medium heat and abundant moisture, but it is found to be very sensitive to continued rain. "A high degree of atmospheric warmth, a good deal of soil warmth, a clear sky during the day and abundant

1 David, Nebel und Erdausdünstungen und ihr Einfluss auf ägyptische Baumwolle. Zeitschr. f. Pflanzenkrankh. 1897, p. 143.

2 Oppel, Die Baumwolle nach Geschichte, Anbau, etc. Leipzig. cit. Bot. Jahresber. 1902, I, p. 374.

dew at night are the chief conditions." After the blossoms open, dry warm weather must prevail. Sandy soil is especially suitable. In soils rich in humus the plant runs to foliage. Clay soil is absolutely unsuitable, since it does not let the water percolate through.

However, examples of adaptation to the climate are known. Thus, Webber and Bessey[1] report that cotton, when carried from the Bahamas to Georgia, did not thrive at first, but gradually adjusted itself to the temperate climate.

However, fogs, even of the English variety, may become disastrous, especially near cities with many factories. P. W. Oliver[2], upon the request of the Royal Horticultural Society, has published the most extensive studies on London fog. The most troublesome admixture is the smoke, the elements of which coat not only the plants but window panes, etc., with a sooty covering. An analysis of this sooty covering shows:

carbon	39.00	per cent.
hydrocarbons	12.30	"
organic bases	2.00	"
sulfuric acid	4.33	"
hydrochloric acid	1.43	"
ammonia	1.37	"
Metallic iron and magnetic oxid	2.63	"
Silicate, iron oxide and other mineral substances	31.24	"

The injuries to plants are usually only phenomena of discoloration. However, different plants are more susceptible; hence the fog may cause the dropping of the leaves. In injuries of the first kind, leaf tips and edges become brown, but the remaining leaf surface is still capable of functioning (Pteris, Odontoglossus, etc.). The dropping of leaves with yellowing and browning, or even without any external signs of injury, is the most frequent result. Sulfuric acid is considered as the cause of the leaf destruction; in addition, Oliver ascribes as an injurious influence also metallic iron. In deciduous plants which remove all the starch from the leaves before they fall, the most important agent exciting abnormal leaf fall is sulfuric acid. Experiments determining a rapidly reduced transpiration show reactions similar to these from fog, if at the same time the light was decreased. I also ascribe the emptying of the cells to the lack of light, for with the action of the acid alone, I found in my experiments that the whole cell contents died quickly and were deposited on the wall.

Of the tar compounds, pyridine was found in fog in especially large amounts. When exposed to vapors of this substance, the leaves became limp and a darker green. The cells were plasmolyzed; the cyptoplasm in the epidermis had turned brown, but the chlorophyll did not change. As a

1 Yearbook of the Dept. of Agriculture, 1899, p. 463.

2 Oliver, F. W., On the effects of urban fog upon cultivated plants. Journ. Hortic. Soc. Vol. 16, 1893; cit. Zeitschr. f. Pflanzenkrankh. 1893, p. 224, und Gard. Chron. 12, 1892, p. 21, 594, 648, etc.

rule, wherever a brown coloration occurred, tannin was found in the cells. The penetration of pyridine, like that of sulfuric acid, takes place chiefly through the stomata. Very similar effects were found also, due to substances related to pyridine, such as *picoline, lutidine, nicotine, thiophene, etc.*

Phenol attacks the foliage very vigorously in aqueous solution as also in the form of vapor, with strong plasmolysis and a brown coloration of the protoplasm and chloroplasts.

The blossoms behaved very differently in relation to fog; at times they showed considerable difference in two varieties of the genus and, in fact, in different petals of the same blossoms. Tulips, hyacinths and narcissus were very resistant.

It is interesting that, as a result of the lack of light connected with the fog, whereby assimilation, transpiration and respiration are repressed, a peculiar yellow-spotted condition often sets in. In this, there is an accumulation of the acid content (because, with the decreased respiration, less organic acids are burned) and an increase of turgescence connected with this seems to lead to cell elongation in the mesophyll (aurigo).

Thus, in considering the effect of fogs, we have to consider two injurious factors, the decreased light and the action of the poisonous substances. This becomes the more dangerous the greater the plant's need of light. Plants adjusted to a lesser supply of light (ferns) are less sensitive.

Only in greenhouses can the injurious effect of such fogs be lessened, and this has been done in England. Special purifying apparatus is made use of (fog annihilators), with which the air entering the greenhouse is passed over strongly absorbing substances (charcoal). For out of door planting only a choice of resistant species can come under consideration.

CHAPTER VII.

RAINSTORMS.

The injurious effects of beating rains on the soil have already been mentioned. They pound the upper surface down or cover it with great quantities of silt. The immediate result is oxygen starvation for the roots. The mechanical effect of heavy rains on the plant itself is first to be considered. There are many natural devices in plants which safeguard the leaves from the beating and tearing effects of heavy rains or the undue accumulation of water from long continued gentle rains. Stahl[1] and Jungner[2] have given a thorough presentation of these conditions and call attention to the formation of the tips and to the position and repeated division of the leaf surface, etc.

The direct results of the rain are a decrease of transpiration and a great water absorption by the roots. They have been less considered. Here also the *swelling of the wood of trees* belongs. Friedrich's investigations[3] show that a constant swelling of the tree trunk (aside from any direct growth) takes place during the night because with lessened transpiration, the tree swells, while in the daytime it shrinks. The differences will be most marked when the growth is rapid and the wood swells, especially when rain comes after considerable drought. Bark and periderm are less affected. Growth and swelling of the wood cylinder are regulated by the influence of atmospheric humidity on the tops of the trees.

It is thus easily evident that smooth bark will crack in places because of the strong and sudden increase in swelling and growth. When the soil is rich and the atmospheric humidity great, these cracks may become open wounds, constantly increasing by bacterial infection. Rough places then arise on the bark of the young tree trunks. These may be observed, for example, in lindens, elms, ashes, maples, etc., near wet ditches and ponds.

The influence of longer periods of rain manifests itself in herbaceous plants, even more than in woody ones, by cracks in fruit and stems. Among

1 Stahl. E., Regenfall und Blattgestalt. Ein Beitrag zur Pflanzenbiologie. Annal. de Buitenzorg.; cit. Bot. Jahresber. 1893, I, p. 49.

2 Jungner, J. R., Om regnblad, daggblad och snöblad. Bot. Not.; cit. Botan. Jahresber. 1893, p. 49.

3 Freidrich, Josef, Über den Einfluss der Witterung auf den Baumzuwachs. Mitteil. üb. d. forstl. Versuchswesen Österreichs. Wein 1897, Part 22.

our vegetative plants, the splitting of cucumbers is most important. The fruit suffered most of all, but sometimes the stems also cracked. Decreased temperature, accompanied by continued rain, not infrequently causes the total failure of harvests, since the cucumbers often show gummosis and are attacked by various black fungi.

Long, cool rainy periods also cause a premature leaf fall, badly developed heads in grain, a small amount of sugar and starch in beets, tubers, etc.

Repeated showers have a very disastrous effect when they fall on blossoming fruit trees and during the setting of the seeds of field crops. In the first place, the insects, necessary for fertilization, cannot fly about so freely, and secondly, the anthers will not open so well, nor will the pollen grains stick so well on the stigma.

Nevertheless, the theory that the increase of bacteria and fungi is always favored by periods of rain does not hold absolutely. Parasitic diseases usually increase only if the rain is accompanied by warmth. On the other hand, cold wet weather retards the growth of the most important parasites (rusts, false mildew, etc.).

In tropical regions, however, rain storms usually favor the development of fungous diseases and, to give at least one example, we will mention Busse's observations[1]. He found that the Phytophthora decay on the cocoa fruits was especialy marked in rainy years. The amount of rain is not decisive but rather the character of the storm. Mighty gusts of rain seem to keep the fungus spores from settling on the smooth-shelled fruit; but the softer, more frequent rains, easily producing stagnant moisture in the depressions in the soil and in the regions where the drainage is poor, have proved favorable for the fungi. Those regions suffer less to which the fresh sea breezes or some wind has unhindered access.

Among cultivated plants in rainy seasons, the wind is a helpful agent in the struggle against parasites. This helpful agent has never been sufficiently credited for its work. The tops of trees should be freed of excessive water by frequent shaking. This should be done especially in closely planted orchards and in warm rainy periods.

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[1] Busse, W., Reisebericht der pflanzenpathologischen Expedition d. kolonialwirtschaftl. Komitees nach Westafrika. Tropenpflanzer 1905, p. 25.

CHAPTER VIII.

HAIL.

All injuries from hail form wounds, with a consequent loss of substance; any chemical action as a result of the cold of the hailstones cannot be demonstrated; only the mechanical blow which either tears away various parts of the tissue and, by drying, causes them to go to pieces, or slits the leaves and branches in knocking off more or less large pieces.

The small piece of rye-blade, which is shown here, has been struck by hail at the points *g*, *z* and *v*, and shows the effects of the blows of the hail stones. In considering such a section after a hail storm which has not been severe enough to knock off the leaves, or heads, or to break the whole stalk, we find, as every one knows, whitish or white spots on the green striped upper surface. The striping is produced by alternate dark green furrows and lighter colored lines. In cross-section, it is seen that these furrows consist of a soft bark parenchyma, containing chlorophyll, while the lighter colored stripes are composed of thick-walled fibre-like cells (*p*). These fibre strands stiffen the blade. The thicker their walls are, the more resistant the blade is and the less inclined to fall. In Fig. 91, the green parts are seen to be changed most. The cells at *g* appear uninjured; at *z* only dry cell walls are found, which are connected with one another by a scaffolding-like structure. Toward the centre of the blade, however, there is green living tissue (*u*). Here, the blow of the hailstone has not destroyed the epidermis (*e*) at all,, but has bruised the more delicate bark parenchyma underlying it so that part of the cells have died. Only a few pieces of the cell walls of the former juicy bark tissue remain and, at this point the hailstone has had such force that it has broken the thick-walled, tough epidermis at *o*. Air has entered through this opening and this hail spot appears white to the naked eye, while at *u* a greenish tone may still be noticed.

Similarly, the loss of tissue will take place in other parenchymatous parts of the plant and the assimilatory activity will fall according to the severity of this loss. Yet, this reduction of the life-activity may become of great influence only if the hail storm sets in at a time when vegetative growth has stopped and the plant has entered upon the reproductive period, when it withdraws the cytoplastic substance from the leaves.

C. Kraus[1] made his observations on barley and describes the effect of hail storms on the grain. He found many heads greatly bent backward and turned, since, after the buds had been hit by hailstones, they were so bruised that only the furtherest developed could free their tips from the outermost leaf sheathing. Heads which had been hit directly were retarded in their whole development; the kernels were lighter, not uniform and often tipped with black. The weight of the heads was about 38 per cent. of the normal, that of the grains about 43 per cent. Kraus found similar conditions in two unbearded wheats, in which, however, because of the absence of beards, the heads had worked their way more easily out of the uppermost leaf sheath. Accordingly the weight of heads of wheat struck by hail was only about

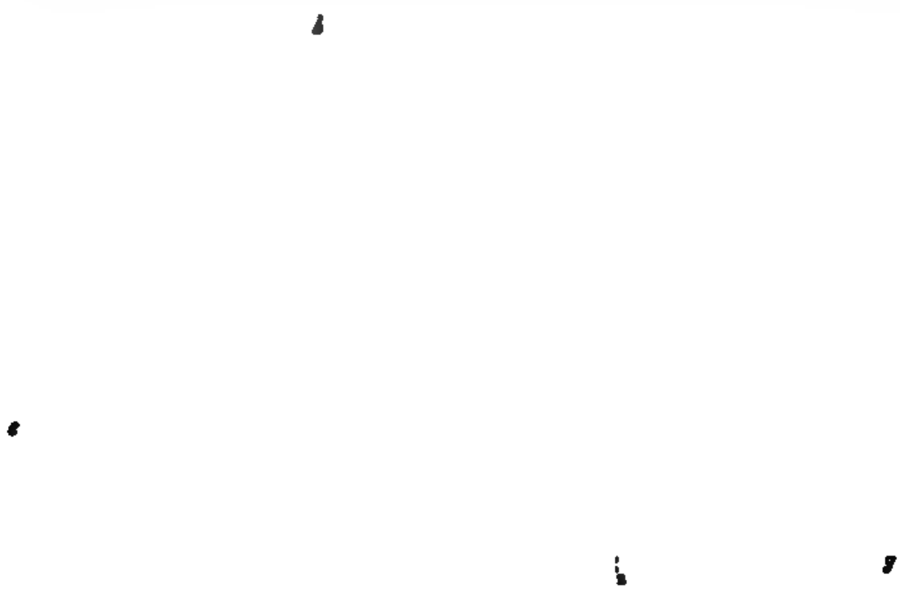

Fig. 91. The effect of hail on a blade of rye. (Orig.)

g healthy green tissue. *z* tissue injured by a hail-stone. *s* adjoining healthy tissue. *v* completely destroyed bark of the blade with ruptured outer membrane (*o*). *h* parenchyma of the blade. *b* vascular bundle. *p* ropes of cells resembling bast fibres.

24 and 15 per cent. and the weight of the grains about 27 and 17 per cent. less than normal.

When the hail storm occurs early in the year, i. e., perhaps in May, many shorter green glades bent at the base are found later between the ripening, upright ones covered with hail spots. The hailstone had probably bent the plant and the blade required more time to straighten and this had delayed ripening.

Wheat seems to be the most robust. I observed after a hail storm in June, 1905, that rye blades showed the injuries represented in Fig. 91, while in the corresponding cell groups of the wheat, the inner tissue was split by

[1] Kraus, C., Wirkung von Hagelschlägen. Deutsche Landwirtschaftl.Presse 1899, Nos. 14-15.

only one tear or was not injured. The epidermis was not torn, but only the walls and contents were browned.

The heads were broken in a very characteristic way. Fig. 92 shows a slight breaking, with the axis making an obtuse angle (*h*). In the more severely injured heads, the axis was bent two or three times, and where bent was almost bare.

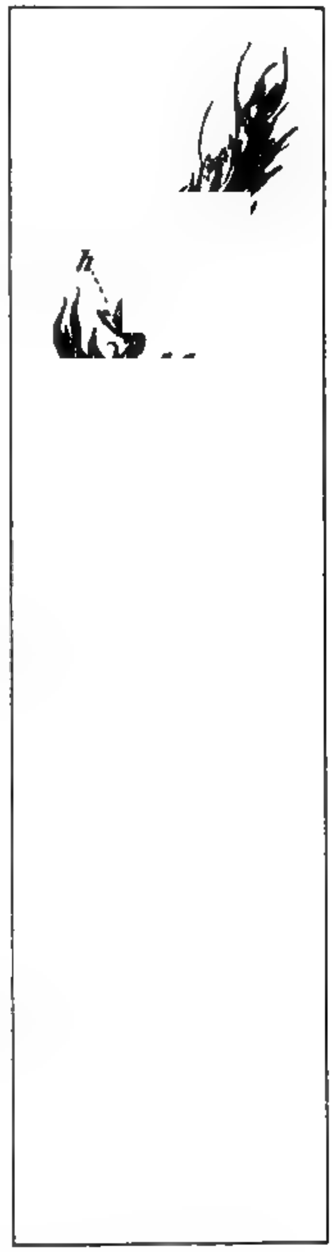

Fig. 92. Head of wheat broken by hail. The grains have fallen at the broken place, leaving it bare. (Orig.)

Fig. 93 shows the construction of the axis where bent: *g*, ducts; *z*, torn parenchyma; *v*, a vascular bundle, which has been killed. Laterally from this, at *br*, the tissue as a whole was a deep brown. Where other heads had been hit the epidermis was torn open; the bordering tissue had collapsed, fallen to pieces and turned brown. Some vascular bundles were found to be almost entirely isolated, since the torn or disintegrated parenchyma had cracked off. This might be a result of tension, since later the still green heads continued their growth. The injuries vary very greatly according to the way the hailstones strike. Kraus's observation shows that after the hailstone had struck the head before it had become rid of the leaf sheath, the beards remained where they were. Therefore, the head appeared bent like a bow. The injuries usually were at the points where the young heads are attached rather than in the internodes of the axes.

Oats will endure severe injuries if the panicles are still enclosed in the upper leaf sheath when the hail storm strikes them. Perfectly sterile heads may be produced and the injury to the plants resembles that of thrip so much as to lead to confusion. In some years I have often found twisted barley heads due to the sucking of thrip. Puppel[1] has often studied the effect of mechanical blows and his illustrations are very helpful. For example, with a heavy smooth roller, he flattened a field of young winter rye which had not yet formed a blade. When the heads began to develop, they were deformed exactly as if they had been injured by hail.

[1] Puppel, Max, Hagel- und Insektenschäden. 40 plates from original photographs.

Wheat, hit by hail on the 4th of June, was peculiarly injured. Besides the well known hail wounds, plants were found scattered throughout the field with a green appearance and almost empty heads. In July, the kernels present were still green and milky. The heads, as a whole appeared a light leather-brown, due to the discoloring of almost all the glumes. Among these were found short, fresh green tips which belonged to the sprouted small heads. These contained six to eight blossom primordia, not one of which had developed, and the uppermost showed only the beginnings of the anthers. The glumes were lancet-like, dark green and as soft as any herbaceous growth, so that a distinct transition to a foliage character was recognizable. In one case young plants had actually sprouted out of the base of some small heads.

Behrens[1] observed similar conditions in hops after a hail storm occurring on the first of July. Four weeks later the blossoming catkins opened

Fig. 93. Cross-section through the stalk of the wheat head of the previous figure, at the place broken by hail (h). (Orig.)

and contained only leaflets. The author's experiments connect this transformation of the inflorescence actually with the destruction of the leaves by hail. On vines from which the leaves had been stripped, the so-called brausche hops grew (see p. 344), while on the stems on the same place which had not been stripped, catkins developed normally.

In potatoes, it has been observed that injuries due to hail reduce the starch content of the tubers[2]. Injury to the pods may seriously affect rape. It is a matter of course that, in all cultivated herbaceous plants, the destruction of the leaf must affect the yield—even to the loss of the harvest. *It would be a mistake to remove foliage* injured by hail. Experiments with cabbage plants showed that better heads were obtained when the injured foliage had been left than when it had been removed.

1 Zeitschr. f. Pflanzenkrankh. 1896, p. 111.
2 Jahresber. d. Sonderausschusses f. Pflanschutz 1903, p. 94.

Internal injuries in juicy fruits, caused by hail, are interesting. Fig. 94 shows a cross-section of a tomato fruit skin struck by hail. We notice at the left, the actual place hit, a hard, dry dark-brown excrescence, the blow of the hailstone did not destroy the epidermis (*e*). The more tender sub-epidermal tissue was fatally bruised and consequently turned brown and dried (*t*). As a result of the further process of swelling, the tissue of the still unripe fruit is torn and transformed to a hard cyst.

Besides this injury, which is most strikingly noticeable, however, a second hard place is found in the juicy flesh of the fruit surrounding a vascular bundle (*g*). The hardness of the tissue arises here because of

Fig. 94. Cross-section through the fruit wall of a tomato struck by hail. (Orig.)

e epidermis of the outside of the fruit, *e'* epidermis of the inside of the fruit wall. *w* dead edge of the wound cut off from the living tissue by plate cork (*t*). *r* cells elongated radially and in part forming dividing walls. *m* normal cells of the fruit flesh *f* the beginning of the formation of plate cork, *g* vascular bundle *h* vascular bundle sheath, *n* division of the cells which are over-elongated radially to form a vascular bundle *k* zone of cork tissue, *st* starch, *z* collapsed cells with swollen cork walls.

suberization, which has affected the whole spot after the cells had begun to elongate and divide freely in the vicinity of the bundles. This has probably been initiated by the change in a ring-like zone (*z*) at a definite distance from the vascular bundle due to the blow from the hailstone or its after effect. Some of the cells have collapsed from the swelling and suberization of the walls; in other cells, the walls have only swelled, while the walls of the adjacent cells have only been suberized. When the hail fell, the fruit was still green and rich in starch and, during suberization, the starch was retained in the irritated tissue zone, while, during the ripening, it has disappeared from the rest of the fruit flesh. On this account, we see a ring drawn about the vascular bundle, composed of deep brown tissue filled with starch (*st*).

Because these cells die and partially collapse, they make possible the elongation of the cells lying directly about the vascular bundle and rich in water. They have elongated in an approximately radial direction, beginning at the sheath of the vascular bundle (*h*) and have divided by parallel cross-walls (*w*). Besides the actual place of injury, the parenchyma of the fruit wall has also participated in the radial elongation (*r*) and only the inner flesh remains normal. On the boundary between the normal and the over-elongated tissue a formation of flat cork (*f*) began at the time of the observation. Joining the corked internal spot, this forms a consistent tough mass.

Similar cork places are met with in pomes, such as apples. Here, too, the blow from hail often causes no open wounds, especially in unripe fruit. We find only depressed places, which later turn practically brown. The depression is produced by the bruising of the parenchyma of the apple skin, lying under the epidermis which has not been injured, and, as a result of which, it has dried and split, usually in radial cracks. Here, as in the tomato, the starch has been retained in the corked tissue, adjacent to the hail wound, in case the apple was still green when struck by the hail. In this case, irregular zones of cork cells in the form of an hour glass are often developed later, which cut off the whole internal hail wound from the healthy flesh of the fruit.

Most significant are the bark injuries due to hail, which, in themselves, as a rule, are of slight extent, but represent considerable damage because of their frequency. So far as I have had opportunity of observing these injuries in fruit trees, I have found that the disturbance in the tissue has not been confined simply to the bruised place but has also spread laterally. In hail wounds on the one year old twigs of the current year, on which they cause relatively the most considerable injury, the disturbance spreads laterally from the actual place of injury in the form of a softening of the bark. As a result of this we see, in cross-section, stripes of parenchyma extending from the dead zone outward and usually filled with starch, pushing into the normal wood and softening it. It thus acquires *brittle and crumbly* properties, which may be of special importance in those trees whose twigs are used as tying and braiding materials (willows and birch). Wounds, due to hail, may often be distinguished from the injuries due to frost by their position in the annual ring. Since hail usually occurs in the hot season, the wounds lie near the end of the annual ring, while frost injuries appear in the spring wood. It is striking that beneath the places hit by hail in the twig of the current year's growth, upon which frost cannot have acted at all, one finds at times in the radius of the wounded place, that the pith is browned and the spiral vessels greatly discolored, since the wood of the vascular bundle, lying between the injury and the pith crown, is healthy. The only possible conclusion is that the disturbance extends back toward the pith through the medullary rays.

Often hail wounds may be distinguished from frost wounds because straight lined normal wood, with numerous vessels, very soon appears again, while, when the frost cracks heal, broad zones of parenchymatous wood may be found, due to the great extension of the adjacent edges. When the hail injury is slight, the bark is not uniformly destroyed, and the cambium continues growing with many gaps.

When bark has been injured it peels at this point very unevenly and unsatisfactorily from the wood. This has an economic effect, since, when oak is grown for the commercial use of the bark, the shoots, struck by hail, peel very unsatisfactorily.

Often hail wounds provide openings for other diseases. If wet weather prevails for some time after the hail storm, decomposition frequently sets in, due to attacks of fungi, etc. In the Amygdalaceae an exudation of gum may set in. Such secondary diseases may later destroy the branches. If this dying back extends to the top shoots of young trees, deformed tops or, in seedlings, crippled trunks are of frequent occurrence.

In fruit nurseries, after a severe hail storm which has *greatly* injured the smooth barked trunks, these trunks should be pruned back almost to the bud, thus renewing the stem. When the tops of older trees have been badly broken and deformed by hailstones, it is advisable to try to reform the top by severe pruning in the following spring. Ordinarily, the power of regeneration is so great in trees that hail wounds heal over easily, but when large pieces have been torn from smooth barked trees by the incessant beating of hailstones, it will be necessary to hasten the closing of the wound by using some tree salve. When the roughened surfaces of the hail bruise have been made smooth by cutting with a sharp knife, they will heal more easily. Then a mixture of loam and cow-manure, free from straw, with ashes or powdered slate kneaded into the form of a salve, should be used.

With the present mania of wishing to cure everything by manuring the soil, it is not surprising that, even in extensive injuries, as from storms and hail, with a loss of substance, fertilizers will be applied at once. We would caution against the use of this; even on poor soil, fertilizers should be used only when the tree has already made new growth. Large wounds which will take some time for healing, are best closed by painting with tree-wax, which flows when cold, i. e., with a mixture of resin, which thus prevents the entrance of water. It is cheaper to coat the wound with coal tar.

In connection with fruit trees and grapevines, Müller-Thurgau emphasizes our warning in regard to retaining the foliage in vegetative plants which has been injured by hail[1].

In growing grapes, a certain hard flavor is mentioned[2]. This is supposedly the result of a fungous infection of the places when hail has injured the grapes. These grapes should be cut out, though the work is very tire-

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1 Müller-Thurgau, Beobachtungen über Hagelschäden an Obstbäumen und Reben. VII. Jahresber. d. Versuchsstation zu Wädensweil.

2 Chronique agricole du Canton de Vaud vom 10 August, 1895.

some. The broken cluster closes again completely as the grapes left grow so much the larger. If the injured vine is to be pruned, this should be begun, at the earliest, a week after the hail storm in order to see how far the plants have recovered. In pruning, as much growth of the current year as possible should be left. It is especially important not to force prematurely lower eyes which promise fruit. By using precaution[1] at least twice as many eyes are left on the vine above the real fruiting eyes as are needed in the following year.

The method of spreading nets of galvanized iron wire over the vines, said to be customary in Piedmont, should be recommended for further testing, as a means of protecting the vines from injury[2].

Recently many experiments have been tried with "cannonading against hail." Nolibois[3] developed the theory of this method. The water vapors arising from the soil are condensed into clouds, the moist dense layers lying lowest. When these lower layers are greatly condensed by the radiation of the soil, the layers directly above them are cooled greatly, occasionally below zero. Any shock is now sufficient to bring the overcooled mist to freezing and precipitation. If the process is continued, there is a constant weakening of the cold action in the upper cloud layers, resulting finally in rain.

According to this theory, declivities would be more exposed to hail than lowlands; lime or sandy soil more than moist alluvial soil; bare soil more than forests; land more than lakes or the ocean. If superimposed cloud layers could mingle one with another so that the temperature is more equalized, and over-cooling hindered, the formation of hail might be prevented. Attempts are now being made to produce such movement of the layers of the air adjacent to the clouds, by the explosion of cannon.

Another theory based on the production of whirlwinds resulting from the mingling of cold air from the mountain with the hot, rising stream of the valley[4], likewise recommends cannonading against hail. In Italy numerous shooting stations have already been formed, yet the reports are very contradictory. More favorable reports on the cannonading of the air have been sent from France[5].

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1 Ungarische Weinzeitung 1896, No. 34.

2 Rho, G., Le reti metalliche a difesa delle viti dalla gragnuola. Bollet. d. Soc. dei Viticoltori. Roma 1892; cit. Zeitschr. f. Pflanzenkrankh. 1894, p. 168.

3 Nolibois, P., Théorie de la formation de la grele; cit. Hollrungs Jahresber. f. Pflanzenkrankh. 1904, p. 73.

4 Bordiga, O., Grandine e sari. Atti del R. Istituto d'incorraggiamento, Napoli, Vol. II, 5 Ser.

5 Praktische Blätter f. Pflanzenschutz, herausg. von Hiltner, 1905, No. 11.

CHAPTER IX.

WIND.

Among the sudden effects of severe wind are the injuries known as "uprooting of trees by wind" and "breaking of tree trunks by wind." In the first, the trunks of the trees are thrown over to one side, taking the root systems with them. In the second, which is economically more injurious, the trunk is broken off.

The action of the storm depends upon the variety of the trees, the stiffness of the individual trunk and its location. In regard to the variety, it may be remarked that tough wooded genera, like birch, spruce, hornbean and redbeech are more often overthrown than broken. Pines and oaks break more easily. The kind of break also differs with the genus. It seems as if pines break off shorter, while the oak splinters and the brittle acacia often shows deep clefts on the stump, extending downward from the broken surface. In regard to the individual firmness of the trunk in the same variety, it is evident that trees, rotten at the core, break most easily. The individual structure of the tree top, which forms the chief point attacked in the lever represented by the trunk, is likewise of importance. The position and the local conditions influencing the structure of the root system, essentially under consideration here, are of the most extensive influence. In deep soil, those trees will endure more wind which have not been transplanted, since in transplanting the tap root has been cut off to make the moving easier. In shallow soil, the advantage of the tap root is lost and the development of the top becomes the important factor. The higher the branching begins on the otherwise smooth trunk, the higher is the centre of gravity, and the more liable the tree is to be uprooted or broken. Pyramidal crowns are therefore probably better than those of a dense spherical form. There are naturally exceptions to the rule; the more exposed the location of the tree, the greater the danger of injury. On mountain slopes it is often noticed that injury due to storms, especially in uprooting the trees, is far less extensive on the windy side than on slopes on which the storm passes downward. Further, whole groups will be overthrown often in the centre of an uniformly old tract of trees. This may be explained by the fact that the wind, in blowing upward, is more uneven and can effect only a small part of the crown of one tree because another standing lower

down on the declivity is directly in front of it. This rising of the tree tops in tiers can often be perceived in forested level costal regions. Only, here the terracing of the tree tops is not produced by inequalities of the soil and trunks equally tall, but by a different height of the trunks, on level soil. It is noticed that where coast winds strike the trees, the outer trees do not grow tall, but are kept down like shrubs. Only at some distance behind these, and increasing with the distance, do they grow to the height of forest trees. Whirlwinds will overthrow whole groups of trees in the centre of an uniform tract. A different natural form of wind protection is mentioned by Schübeler[1] (see p. 253) for spruce families, from the Gudbrandsdal, at an elevation above sea-level where the spruces approach their height limit. The trees are usually arranged in rows in exposed places, and in fact in such a way that the main trunk stands at the side turned toward the prevailing wind, while the branch suckers form a pretty straight line behind the parent tree. Therefore, only where this parent tree keeps off the wind is it possible for the young sucker trees to grow up.

In the tropics the cultivation of *cocoa* is often affected by the wind storms. Aside from the indirect losses from overthrown shading trees, the wind also directly tears apart the forkings of the main branches. According to L. Kindt's reports, an attempt has been made to produce tall tree trunks from the remains of the bush forms, injured by the wind, by letting one of the many water sprouts grow up and then forcing it, by topping, to form branches. This process has been found partially advantageous, but has been entirely abandoned by Kindt upon his own experience. He found that in such an artificial formation of the trunks, contrary to the nature of the tree, only scanty, weakly leaved crowns formed of short horizontal branches are produced in which fruits, ripening prematurely, are found only on the trunks. The yield is not satisfactory quantitatively and qualitatively, not only in the first year, but also in subsequent years.

The duration and time of the storm, as well as the prevailing weather, should be taken into consideration. In rainy periods, the softened soil gives way more easily and predisposes toward the uprooting of trees by wind (see Sewage Fields), while a spring storm on frozen soil finds the trees more firmly anchored and, with increasing strength, causes more windbreaks.

Aside from these gross injuries occurring at once, however, those should also be recorded which do not destroy the existence of the individual but only weaken it temporarily or permanently.

Among wind damages belongs *an inclined position of the trunks.* The most striking and frequent phenomena are offered by street trees, especially where gutters run along both sides of the avenue or highway. The striking discovery may be made here, that if the street runs perpendicularly to the prevailing direction of the wind (with us usually a west wind), the most exposed rows of trees have comparatively erect trunks, while those on the

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1 Schübeler, Die Pflanzenwelt Norwegens. Christiania 1873-75, p. 163.

other side are more or less bent, overhanging the gutter and often exhibiting a curved growth. The inequality of the root support is evident from this. On the windy side of such a street, where the wind first strikes the surface of the gutter, the root system has developed differently; on this side, the roots cannot extend as far but are strongly fastened within the street dam. The wind pressure finds in this support a sufficiently strong counterbalance; on the other side of the street, the conditions are reversed; here, to be sure,

Fig. 95. Two wind bent and broken spruces; the tree on the left has two witches' brooms and three secondary tips. (After Klein.)

the roots are better developed in the street itself, than on the side toward the gutter, and form the anchoring apparatus which counteracts the *strain* of the bending trunk. The propping side of the roots lies toward the gutter and, being weakly developed, causes the tree to incline toward this direction. It seems, therefore, that the tap root planted at an angle against the direction of the wind will form the most effective protection of fruit trees. Guy wires attached on the windward side are more commonly used, and serve also to relieve the strain of the tree, but may well be considered less useful.

This "sabre" or curved growth is explained by the annual bending by the wind when the shoots are forming in the spring and summer. The tip of the trunk, continuing its growth at this time, tends always to maintain the perpendicular position and bends only as the tree is quickly blown toward the horizontal. All that has been said here, in reference to the main axis, refers also to all branches which, in windy positions, actually produce a *one-sided, flag-like top.*

The flag-like character results from branches bending away from the wind (with us toward the east) and from the scanty branching, with a considerably longer main shoot, while the branches growing against the wind remain shorter and at times die back.

Ludwig Klein[1] gives very instructive examples in two spruces from the pastures above the road Haldenwirthshaus-Wiedenereck. The trees on the windy side had lost their branches almost entirely, as if one-half of the top had been cut off with scissors (*the pruning action of the wind*). This is ascribed by Klein to the drying action of the wind. To the effect of the wind is added an appreciably greater warmth and consequently increased transpiration.

In fruit trees, the flag-like tops often bear fruit only on their outer edges, since the interior growth is too dense. When the trunk has been considerably bent from the perpendicular, a great difference in nutrition shows itself between the upper and under side of the branch in the production of a more luxuriant foliage on the upper half. The attraction of the luxuriant wood shoots for the raw food substances from the soil, brought from the roots, increases in proportion to their development. The more they utilize this solution, the more is lost for the horizontal part of the tree top, and consequently some branches are pressed downward and begin to die, while the new leaf axes shoot upward in the perpendicular and *form water sprouts.* Thus is caused a sterility of many years duration. In various forest plantations near the coast, this one-sided development of the crown is also noticeable. The drying of the branches at any rate may be traced partially to the constant rubbing due to the wind. The difficulty of reforestration of coast stretches should not be explained by the salt content of the sea winds, as is often done[2], but simply by their mechanical action.

The stunted forms of trees on coasts and upper limits of the tree line is, in most cases, due to the wind. The tips are partly dried and broken off by the wind. The weight of snow on the branches may have the same result. In the next period of growth the tree attempts to develop a new top shoot from one of its lateral eyes, which succeeds in conifers only when there is local protection, and only rarely in stormy regions. As a result of the broken top, the lateral branches grow with increased rapidity and often,

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1 Klein, L., Die botanischen Naturdenkmäler des Grossherzogtums Baden usw. Karlsruhe 1904, Fig. 26.

2 Anderlind, Leo, Bericht über die Wirkung des Salzgehaltes der Luft auf die Seestrandskiefer (**Pinus Pinaster**). Forstl.-naturwiss.. Zeitsch. 1897, Part 6.

well covered with needles, lie on the ground. Preda[1] describes a good example from the Livornian coasts. Besides the slanting trunks, varieties of pine and holly *Juniperus phoenicea and Tamarix gallica* are found bent like snakes and the interwoven branches of Phillyrea and other bushes creep over the ground. Hansen[2] gives a very similar description from the Island of St. Honorat near Cannes.

Bernhardt[3] characterizes certain regions in Germany as centres especially frequently visited by storms. As examples should be named Schwedt a. O., the Silesian mountains, the Bavarian and upper Palatinate forests, the forests of Franconia and, in a limited way, also the North German coast (Mechlenburg, Holstein). In these coast lands, northeast storms in general prevail as frequently as west and northwest storms, while in Southern Germany, west and southwest winds have a decided preponderance; in Northern Germany, as a whole, west and northwest winds.

It is certain that the distribution of plants will adjust itself to the wind conditions, since the varieties which withstand wind better have survived. Schröter and Kirchner[4] quote, for example, Müller's explanation of the distribution of the tree-like mountain pine (*Pinus montana*) in the Alps. Formerly this was found over a larger area, but because of its slow growth, need of light and lesser demand had become limited to places where a different forest vegetation cannot develop, viz., to wind-swept places with scanty atmospheric humidity above the forest line. This wind resistance capacity of the pine is probably connected with the anatomical structure of the needles. Zang and Scheit consider the so-called transfusion tissue of the vascular bundles a precautionary structure which, because of its constant water content, makes possible the life of the needles in continuous dry air[5]. Nevertheless, naturally, a definite limit may not be exceeded and Zang[6] cites as an injury due to wind, the yellowing and drying of the tips of the needles.

Certainly in conifer needles, the heavy waxy coating of the epidermis and the schlerenchymatic sub-epidermal cell row, just as in the cacti, succulent Euphorbiacae and Crassulaceae, increase the resistance to wind. Gerhard[7] emphasizes, for the Cape flora, as a further protective arrangement, the reduction of the intercellular spaces and the depression of the stomata. He emphasizes the development of sclerotic hypoderm fibres and the strengthening of the edges of the leaf by collenchyma or bast bundles as a mechanical effect due to the wind, which manifests itself in spite of the moisture of the soil.

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1 Preda, L., Effeti del libeccio, etc. Bollet. Soc. Bot. ital. 1901; cit. Zeitschr. f. Pflanzenkrankh. 1902, p. 160.

2 Hansen, A. Flora oder Allgem. Bot. Zeitung 1904, Vol. 93, Part I, p. 44.

3 Die Waldbeschädigungen durch Sturm und Schneebruch usw.; cit. Forsch. auf dem Geb. d. Agrikulturphysik 1880, p. 527.

4 Kirschner, Loew und Schroeter, Lebensgeschichte der Blütenpflanzen Mitteleuropas. Vol.I, Part III, p. 207.

5 See Scheit Die Tracheidensäume im Blattbündel der Conifren. Jenaische Zeitschr. f. Naturwiss. XVI. 1883.

6 Zang, W., Die Anatomie der Kiefernadel usw. Dissertation. Giessen 1904.

7 Gebhard, G., Beiträge zur Blattanatomie usw. Dissertation, Basel; cit. Bot. Jahresber. 1902, II, p. 293.

The very interesting results of experiments made by G. Kraus[1] to explain sabre growths and other tree forms, induced by the wind, are of great importance. If a fresh growing shoot of an herbaceous or woody plant be bent so that its tip overhangs, the concentration of the cell sap on the convex side has become more concentrated. The increased sap concentration of the convex side is due to an essentially higher sugar content. This sugar is newly formed when the shock takes place. This noteworthy peculiarity is exhibited not only by the trunk and branches, but also by the half grown and fully grown petioles. The sugar formation, however, is not connected with the deformation but depends on the motion as such, and frequently when the sugar is formed, the free acid disappears. Ferruza[2] observed in palms and succulents that such interference increased the transpiration; after Wiesner[3] and Eberdt[4] had shown that the wind hastened the transpiration. It was found by Kohl[5] and Baranetzky[6] that even very slight interference would increase the amount of evaporation. Reference should be made to Burgerstein in regard to further literature[7].

The local distribution of the sugar warrants the conclusion that it is a preliminary step, if not a direct one, in the formation of cellulose in the plant's metabolism, and it should be stated that, with the increased sugar formation in the parts of the plant moved by the wind, the formation of cellulose and the development of the cell wall will be hastened. It is a comparatively rare occurrence that plant tissues remain in the stage of their development in which sugar is formed. More frequent is the process, especially in growing shoots, that the sugar disappears to the same extent as the cells become thicker walled. We will, therefore, scarcely go astray in stating that deformations, resulting from the action of the wind, are more stable, since the convex side of the bend forms sugar and cellulose more easily; hence its growth is completed sooner. If we consider that the place bent is more favorable for the action of light and warmth, then the early termination of the period of cell elongation is really a matter of course. The branch hardens sooner and does not grow so long; hence, therefore, the compact structure of the windward side and the slender, almost whip-like branch formation on the side protected from the wind.

No more thorough discussion is necessary to understand the fact that seed beds and young plantations in light soils may at times be blown to pieces, that surface soil may often be blown away and become sterile because of the sudden imprudent removal of protective strips of forest and that

[1] Kraus, G., Über die Wasserverteilung in der Pflanze, II. Der Zellsaft und seine Inhalte. Sep.-Abdr. aus d. Abhandl. d. Naturf.-Ges. zu Halle, Vol. XV; cit. Bot. Zeit. 1881, p. 389.

[2] Ferruzza, G., Sulla traspirazione di alcune palmi, etc.; cit. Bot. Jahresber. 1899, II, p. 124.

[3] Wiesner, Jul., Grundversuche über den Einfluss der Luftbewegungen auf die Transpiration der Pflanzen. K. K. Akad. d. Wissensch., Wien, 1887, Vol. 96.

[4] Eberdt, O., Transpiration der Pflanzen und ihre Abhängigkeit von äusseren Bedingungen. Marburg 1889, p. 82.

[5] Kohl, F. G., Die Transpiration der Pflanzen. Braunschweig 1886.

[6] Baranetzky, Über den Einfluss einiger Bedingungen auf die Transpiration der Pflanzen. Bot. Zeit. 1872.

[7] Burgerstein, Transpiration der Pflanzen. 1904.

precaution can be best taken against the various injuries due to wind by means of a protective plantation, suited to the conditions.

We now come to wind-caused *injuries to the leaf.* The fact that leaves become slit or remain hanging, dried and sear, on the branches in places where wind frequently increases to a storm, is so frequent an observation, especially in coast regions, that it need not be taken up thoroughly here. Just as little need the injuries be touched upon here which are produced in unfolding leaves, by the *rubbing of the leaf edges*[1]. Places thus rubbed through are found with great frequency in horse-chestnut and beech leaves, which, still folded, break from the bud. Young branches are also injured by rubbing, as may be observed in the young shoots of pears and weeping willows (*Salix babylonica*) after stormy days in summer. Here belongs, further, the whipping of hop vines, whereby the catkins at times become prematurely ripe and red[2]. The dried edges of the leaf are more important, and as yet but little observed. Since many causes may lead to blighted edges, one must distinguish whether the dried and discolored edge forms a connected outline or one interrupted in places, or whether dry, discolored places push further into the leaf surface from the dead part of the edge (frequently wedge-shaped between the main ribs).

Only the dry, browning or blackening outline may be considered as a simple wind injury, as Hansen determined experimentally[3]. This investigator constructed[4] an original apparatus for producing wind in order to eliminate secondary factors (light, excessive heat, drought) which co-operate in the injuries due to wind, occurring out of doors.

From these experiments, he found, first of all, that *passing currents in the air* dry the tissues most. A simple striking of the wind against a plant growing against a firm wall is frequently less injurious and, under certain circumstances, actually without effect because the wall throws back the wind current.

In the experiments carried out with this apparatus, a wind continuing day and night, lying between 1 and 2 of the Beaufort scale, was used. All the individual leaves of tobacco plants, standing in pots, after 24 hours had slight brownings of the edges, while the remaining part of the leaf blade was perfectly healthy and showed no trace of wilting. On an average, the mature leaves suffered sooner than the immature ones. The drying of the tissue always began near the thinnest peripheral veins. The mesophyll collapsed, did not contain air but rather appeared translucent, "as if injected." The cell content was deformed, the chlorophyll grains could not be clearly recognized. In many cells, the protoplasm contained slightly brownish granules; the vascular bundles had turned brown; the boundary between

[1] Caspary, Bot. Zeit. 1869, Sp. 201. — Magnus, Verh. d. Bot. Ver. f. d. Prov. Brandenburg. XVIII, p. 9.

[2] Beobachtungen über die Kultur des Hopfens. 1880. Herausgeg. v. Deutsch. Hopfenbauverein.

[3] Hansen, A., Experimentelle Untersuchungen über die Beschädigung der Blätter durch Wind. Flora oder Allgem. Bot. Zeit. 1904, Vol. 93, Part I.

[4] Ber. d. Deutsch. Bot. Ges. 1904, Vol. XXII, Part VII, p. 371.

dry and healthy tissue was sharp and, in the latter, the vascular bundles not discolored. Hansen's explanation is that "the current of air fast robs the vascular bundles of their water, and so changes them that they can no longer act as conductors. Thus the mesophyll dries at this place." This might also be the secondary process and the drying of the conducting cords the primary one, while as yet the drying of the parenchyma of the edge is usually looked upon as the direct effect. In opposition to this, Hansen says: "If one wishes to assume that the wind directly attacks the mesophyll, then it would not be possible to understand why the process of drying should not begin also in the middle of the lamina."

Bruck[1] takes up the matter in the same way. He observed that in general only those leaves with the secondary veins extending to the edge, suffered peripheral injury, the so-called caspedodromous or cheilodromous (extending to the edges) venation. (Fig. 96.) Tree leaves from the same region, which did not exhibit the injury, had "more or less camptodromous, or rather brochidodromous, venation; their course is curved or looped without ending at the edge of the leaf." In the latter form of venation, Bruck perceived a decided protection of the leaves against drying from wind. Browning of the vascular bundles is very similar to that produced by frost.

Fig. 96.
Craspedodromous venation. Camptodromous venation.
(After Bruck.)

According to my studies on the production of dry edges of leaves as the result of the action of gases, the process of dying was different here. In the action of the gases in smoke, the tissue did not become translucent previously and the walls of the bast elements color yellow to brown; the cell content dried together as a whole to an approximately uniform substance. The vascular bundles of the peripheral zone also were altered, but I explained the earlier death of the peripheral leaf mesophyll by the fact that even if the fine ends of the vascular bundles still supplied water normally, this was not sufficient to cover the increased loss due to the action of the acid. It might be just the same in the dried edges due to the wind. The evaporation in the mesophyll, increased by the wind, may very well be the primary process. The loss of water in the leaf is relatively greater at the edge, since the upper surface is too large in proportion to the tissue mass and the water conducting system consists of too few elements, i. e., is insufficient. At the places where the leaf is thicker and the venation more developed, the tissues receive more water and retain more, since here the same evaporating surface, as at the leaf edge, has a

[1] Bruck, W. F., Zur Frage der Windbeschädigungen an Blättern. Beihett z. Bot. Centralbl. Vol. XX, Section 2, Sep.

much more juicy parenchyma back of it. On this account, close to the larger veins, we find strips of tissue which discolor and dry last.

In this section many striking diseases, held to be due to wind, have not as yet been sufficiently studied. An example may be found in the so-called Mombacher diseases of apricots, which Lüstner[1] considers is due to wind. In Mombach, near Mainz, apricot leaves dry back from the tip and edge, and fall. Sometimes only the dried edge falls, while the rest of the leaf is left on the tree. Lüstner considers this a wind disease, while Bruck's opinion[2] is that it is a result of sunburn.

It is more necessary to protect garden plants against the raw spring winds than against frost. For example, it was observed in April, 1905, that young rhubarb leaves, which withstand frost if they thaw slowly and without being touched, were much injured when the frozen leaves had been struck by the wind. In the same way young rose shoots were injured only where blown by the wind. While in protected places, young vegetable and flowering plants stood in perfect condition; they were destroyed where the wind had free access[3]. Besides the increase in the amount of evaporation, the mechanical rubbing of the still tender organ is very destructive.

In blowing the snow away, the wind does great harm. The seeds of various species live in furrows on the side away from the wind even with a minimal snow covering, while they die on the windy side.

Only a properly constructed protective plantation can decrease the injuries due to wind. By proper construction we mean, in the first place, the imitation of the system which nature adopts in coast regions, and, in the second place, the proper choice of trees.

The natural system consists in the planting of the lowest growing bushes on the windy side; they are stunted or branches die back where beaten by the wind, but these dried branches break the force of the wind, letting the opposite side develop. If higher bushes are planted behind, they remain protected as far up as the height of the first plantation. If they exceed this their growth becomes stunted and one-sided, yet, nevertheless, they grow somewhat higher and in turn give protection to a tree planted behind them, until finally all the trees can grow well.

Where there is chance that shifting sand may cause trouble. H. Neuer[4] recommends especially *Populus alba* and varieties of Salix. As intermediate plants *Ailanthus glandulosa* and *Rhus Cotinus* thrive well. Among bushes, *Liqustrum vulgare, Cotoneaster buxifolia, Spiraea opulifolia,* Tamarix and *Ribea sanguineum* are especially valuable. Of decorative plants, Pelargoniums, Chrysanthemums and stocks should be used first of all.

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[1] Lüstner, Beobachtungen über die sogen. Mombacher Aprikosenkrankheit. Ber. d. Kgl. Lehranstalt zu Geisenheim am Rhein. Berlin 1904, p. 222. Paul Parey.

[2] Bruck, loc. cit., p. 74.

[3] Böttner, Joh., Rauhe Winde. Prakt. Ratgeber im Obst- und Gartenbau 1905, No. 8.

[4] Neuer, H., Neue Erfahrungen über Anlagen und Pflanzungen an der Nordseeküste. Die Gartenwelt 1904, No. 49.

CHAPTER X.

ELECTRICAL DISCHARGES.

Flashes of Lightning.

In spite of numerous descriptions of destruction in the plant world, due to lightning, we have not yet acquired an exact knowledge as to the way the lightning acts. Just as in frost injuries, often similar to those produced by lightning, we must distinguish *mechanical and chemical action;* in lightning the mechanical action may be the more important one. Cohn[1] compiled 41 cases where lightning had struck and an abundant bibliography. He states that when lightning strikes, the main current of the electricity, after breaking through the bark, passes down the tree through the cambial layer, which is a good conductor. "The heat developed by the action at once vaporizes the liquid contents in the cambial cells entirely or in part. The vapor, under pressure, either bursts the bark, with the bast clinging to it in strips or larger pieces. These broken pieces are frequently thrown off to great distances. Besides this main current, a secondary current in the poorly conducting wood will cause it to split where it is least firm, as a result of the sudden drying due to the evaporation of the sap. Therefore, according to Cohn's theory, neither the split wood nor the torn off strips of bark should be considered as signs of the course of the lightning but only as indicating the region of the least resistance. With Caspary, I would rather think that the torn strips are the actual traces of the lightning.

Cohn based his assumption that a sudden vigorous formation of vapor due to evaporation in the tissue, struck by lightning, caused the explosive scattering of the bark and wood splinters upon the following evidence. First of all, dried splinters were actually found. It is possible, however, to observe this only rarely since, as a rule, the storm is accompanied by a downpour of rain which immediately wets the dried chips. The fact that trees may be set on fire by lightning, also favors the drying action. It should be stated here, however, that as yet it has not been proved absolutely that

[1] Cohn. Ein interessanter Blitzschlag. Verh. d. Kais. Leop. Carol. Akad. d. Naturf. Vol. XXVI, P. I. — Über die Einwirkung des Blitzes auf Bäume. Denkschrift d. Schles. Ges. f. vat. Kultur 1853, p. 267.

perfectly healthy trees have been set on fire[1]; rather most investigations show that only trunks rotten at the core were set on fire.

The individual condition of trees, as well as the intensity of the lightning, governs the extent of the injury. It is found that different varieties of trees frequently show similar injuries and that certain kinds are especially apt to be struck by lightning, while others rarely.

It should be stated, first of all, in regard to the nature of the injuries that in most cases the torn bark exposes the wood, but that with varieties which are good conductors, and in young trees, lightning may strike, leaving no visible injury. As a rule, lightning does not strike the tip of the pyramidal poplar, but further down on the trunk, so that most of the top remains uninjured; the lightning then passes down the trunk in a splintered line which is straight or only very slightly spiral. Wood and bark splinters are thrown off; on the edges of this strip the bark is raised from the wood, the edges themselves are not discolored. In the oak, however, the tip is often struck and frequently large branches at the top are killed and broken off. The splintered strip usually exhibits a strong spiral twisting[2] on the trunk, its wood a more channel-like, hollowed lightning path, while, in the poplar, sharply angled splinters indicate the course of the flash. Especially in oaks, besides radial splits, the lightning also produces many tangential ones in the direction of the annual ring. At any rate, the direction and form of the line of splitting depend on the structure of the wood. The lightning follows the path of best conduction; hence the more the wood fibres are twisted, the more the splinters are twisted. In Fig. 97 F. Buchenau and Nobbe[3] reproduced their observations on oak and show the spiral course of the line of splitting especially well. Caspary's experiments on the effect of the sparks from the discharge of a Leyden jar, loaded with 50 volts, confirmed the fact discovered by Villari that the electrical spark can travel a much longer distance longitudinally in the wood than transversely. Besides this, wood offers a greater resistance to the spark in a tangential direction than in a radial one. The relations of the extent and the place struck in longitudinal, radial and tangential directions are, according to Caspary, in fresh linden wood as 19: 2: 1, in dry spruce wood, as 7: 2: 1. The tissue was always torn in the course of the spark and an extensive destruction of the cell contents was perceived as a result of the heat.

This result from the lightning could be demonstrated everywhere and in the cases where no injury is outwardly recognizable, a narrowly limited, easily overlooked point of entrance may never be lacking. Colladon[4] also observed, for example, in a poplar and a spruce, especially characteristic

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1 Caspary, Mitteilungen über vom Blitz getroffene Bäume und Telegraphenstangen. Schriften d. phys. ökonom. Ges. zu Königsberg 1871; cit. Bot. Z. 1873, p. 410. Beyer, Blitzschlag. Verh. d. bot. V. d. Prov. Brandenb., 28 Jan., 1876.

2 Buchenau, Abhandl. d. naturwiss. Ver. zu Bremen, Vol. VI. — Schriften d. Leopold. Akad. d. Naturf., Vol. XXXIII, 1867.

3 Döbner-Nobbe, Botanik f. Forstmänner. 4. ed. Berlin, P. Parey, 1882, p. 34.

4 Colladon, Die Wirkung des Blitzes auf Bäume; cit. Biedermanns Centbl. 1873, p. 153. Bot. Z. 1873, p. 686.

circular places on the surface from which the bark had been removed. These places seem to be produced as a result of the very great local drying of young wood and were colored by concentric, dark yellow and brown

Fig. 97. An oak 23 m. high, which has been struck by lightning. (After Nobbe.)

a place where the split-off branch had joined the trunk *b*, *c* *d* branches injured at their base which have dried later, *e* branch remaining uninjured. *II* and *III* hanging pieces of wood *x* and *y* small branches injured in the sapwood

rings. A number of other causes have also become known, in which small, circular spots indicate the entrance or exit of the flash of lightning.

R. Hartig, in his text book[1] gives especially clear illustrations of the different kinds of injury due to lightning. He traces the difference in the

[1] Hartig, R., Lehrbuch d. Pflanzenkrankheiten 3d Edition, 1900. Berlin, J. Springer.

lightning paths to the unequal conductivity of the tissues and to the degree of mőisture present in them. If rain has fallen, weak flashes of lightning cannot penetrate into the interior of the trees, but only tear off pieces of bark, lichens and dry branches. Trees which have a very delicate cork layer, as, for example, the pitch pine, display sometimes very noteworthy traces of lightning only in the outer bark tissue. Often only ***small, round, isolated places in the bark*** or others ***connected by zigzag lines*** are killed, which later loosen from the living bark of the tree, often after a preceding formation of cork. In trees with a heavy periderm, the lightning must first strike through this poor conductor in order to reach the inner bark, which is a good conductor Hartig considers the outer layers of the inner bark "which are poor in fat" as especially good conductors, while the tissue rich in protoplasm and, as a rule, containing much fat in the newest layers of the inner bark, is a very poor conductor on account of its fatty contents and often entirely escapes the lightning. The best conductive tissue is the young wood, having only scanty cytoplasmic wall coatings. This is also found to be very susceptible to frost injuries. If (in powerful discharges) the cambial layer is also injured, there results an "internal healing."

The theory of the influence of the fatty contents on the conductivity of the tissue is based on the works of Jonescu[1]. He found that the electric spark struck through fresh wood the more poorly, the richer this was in fatty oil. In the same plantation the beech is rarely struck by lightning, while the oak is most frequently injured. A microscopic investigation showed the reason: the wood cells of the beech contained oil; those of the oak were almost free from it. Other *"fatty trees"* (in which in winter and spring all the starch is turned to oil), as for example, ***Juglans regina, Tilia parvifolia,*** Betula, Pinus, were also found to be bad conductors when compared with starchy trees (Acer, Corylus, Fraxinus, Ulmus, Crataegus, etc.). If the oil was removed from the fatty trees by ether, sparks penetrated the fresh pieces of wood just as easily as that of typical starchy trees. It should not be forgotten, however, in judging from these conditions, that the oil content in the different tree varieties changes in different seasons of the year; from this it is evident that their electrical conductivity varies. Jonescu found with equally large pieces from the trunk of *Tilia parvifolia* that in February, when wood and bark are rich in oil, a much higher electrical tension was necessary than at the end of March, when the young wood was filled with starch and glucose. The converse is true in the beech, which from January to April, is rich in starch, but in May is rich in oil, as also the pine, spruce, hornbean and common oak. The pine is pretty often struck during our summer storms. At this time it contains glucose in its wood, bark and pith and starch in its medullary rays. But in winter, the tree contains very finely distributed oil and it is seen that in countries with winter storms (Ireland,

1 Jonescu, Dimitrie, Über die Ursachen der Blitzeschläge in Bäumen. Jahresb. d. Ver. f. vaterl. Naturkunde in Würtemberg. 1892. Schweizerbartsche Verl. — Weitere Untersuchungen über die Blitzschläge in Bäumen. Ber. d. Deutsches Bot. G. 1894, p. 129.

Norway) lightning almost never strikes pine trees. These differences in the composition of the cell contents, however, become of less importance if the place of growth causes a high electrical tension, as, for example, if the tree stands on impervious layers of soil where water has collected, or on the banks of rivers, ponds, etc.

Fig. 98. Cross-section through a spruce with numerous overgrown wounds due to lightning. (After Hartig.)

The water content of the wood plays a very small part in this question of the attraction of lightning by trees.

The electrical spark under high tension seeks the shortest path and then strikes through even poorer conductors.

Often in the course of years a tree will be repeatedly struck by lightning and cases will thus occur when a trunk shows small roundish or longish traces of lightning on its whole outer surface which might lead to the suspicion of hail injuries. Hartig (loc. cit., p. 241) thinks, however, that the

characteristic form of the lightning tissue in young wood would remove all doubts. Such a picture of repeated and healed injuries, due to lightning, is shown in Fig. 98. A similar constitution of the trunk could also indicate frost wounds, only here the protruding frost cracks are lacking. Otherwise, however, the anatomical changes in the tissue which set in in the sap wood during the healing of the wounds due to lightning also exhibit a very great similarity to that formation of parenchyma wood which usually follows a frost injury. Since we will later consider the latter more closely, we will give here, only for the sake of later comparison, R. Hartig's picture which v. Tubeuf has recently reproduced[1]. We see in the lowest, thick-walled

Fig. 99. Cross-section through an annual ring of a spruce in the year it was struck by lightning. The crumbled cell layer shows the effect of the lightning. (After v. Tubeuf.)

tracheid layer (Fig. 99) the end of the previous annual ring. The new annual ring has begun with the formation of thin-walled elements and was struck by lightning when the 10th to 12th summer tracheids had been formed. The action of the lightning consists in the fact that the latest wood elements have been displaced, slantingly pressed together, as if by a tangential pulling, and in part killed, while the cell layers, remaining capable of life, have developed into parenchyma wood and then gradually passed over again into small celled normal wood.

Healed wounds due to frost exhibit the same processes; only, as a rule, *the abnormal layer of parenchyma wood* is found nearer the *old annual ring.*

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[1] v. Tubeuf, Über sogenannte Blitzlöcher im Walde. Naturw. Zeitschr. f. Land- u. Fortswirtsch. 1906, p. 349.

This difference may be due to the fact that the disturbance from late frosts occurs usually when the trees have formed but little new wood, while the injuries due to lightning are produced by summer storms later in the season.

R. Hartig did not consider that the production of the collapsed strip of tissue was the direct result of the action of lightning, for he says[1], "if the lightning takes its course, entirely or in part, in the young wood, it is seen in this, that the cells remain unlignified and are pressed together by the tissue structures produced later." He then gives statements, as does also Beling[2], on the death of whole groups of trees in which he found[3] that the *bast* was apparently killed in the pines struck by lightning and in numerous adjacent trunks. The same observer also mentions a case in a mixed spruce and oak forest, in which the spruces predominated, wherein only the repressed (12) oaks showed traces of lightning, while the spruces were entirely uninjured. The fact that, in mixed tracts, the oaks suffer with especial frequency from lightning has often been mentioned; just as also that other trees, not distinguished possibly by their height and structure, in certain localities fall victims especially to the lightning flashes[4].

In connection with the death of trees in whole groves, R. Hartig lays emphasis on his observations that this advances radially in tracts of pine trees. v. Tubeuf[5] has recently studied this condition. He describes a case in which only one larch apparently had been struck by lightning and yet a considerable number of the surrounding pines and spruces began to die. The larch showed an interrupted line of splitting extending down the trunk, the top remaining green. The trees surrounding it showed no local injuries, but died in a semi-circle of 25 m. Such cases have often been found. In an earlier publication v. Tubeuf[6] states the hypothesis that such dying back of large groups of trees is caused by "lightning spray," i. e., by the scattering of the lightning into a number of rays pencils; while Ebermayer[7] traces the phenomenon to an *internal lightning stroke,* due to the sudden union of electricities which had been separated. Through the influence of the thunder cloud the opposed electricities divide in the tree; the unlike, negative, draws up to the upper part, while the other, positive, presses down into the lower part. "Now as soon as the lightning strikes, the cause of the separation of the two electricities inside a nearby body is removed and these suddenly reunite in the same moment." v. Tubeuf cannot adopt this point of view on the ground of the results of his artificial lightning experiments. In the investigation of trees taken from lightning depressions, he found, "coarse injuries due to lightning" in one or another trunk, and since other

1 Hartig, R., Lehrbuch der Pflanzenkrankheiten. 3d ed. 1900, p. 242.
2 Zeitschr, f. Forst- u. Jagdwesen, Nov. 1873.
3 Bot. Jahresbericht v. Just, 1875, p. 956. — Lehrbuch d. Baumkrankh. 1882, p. 191.
4 Landwirt 1875, p. 400 u. 513. — Gard. Chronicle 1878, II, p. 667.
5 v. Tubeuf, Über sogenannte Blitzlöcher im Walde. Naturwiss. Z. f. Land- u. Forstwirtsch. 1905, p. 493. (Bibliography here.)
6 Absterben ganzer Baumgruppen durch den Blitz. Naturwiss. Z. f. Land- u. Fortswirtsch. 1905, p. 493. Bibliography here.
7 Ebermayer, Wald und Blitzgefahr. Naturwiss. Rundschau. 1899.

causes of death (animal and fungi enemies) were proved to have been excluded, he came to hold the opinion that spray lightning must exist. A division of lightning into two branches was observed by the head forester, Petzold, in the forestry district of Sachsenreid[1].

Blight of Conifer Tops.

In 1903 v. Tubeuf[2], using numerous illustrations, described a case of very extensive blighting of conifer tops in upper Bavaria. These observations led to the conclusion that only one cause, acting once, in the winter of 1901-1902, could have existed and that it must be sought for in an equalizing of the electrical potential in *winter storms.* The characteristic symptom is the manner of dying. In the upper part of the tip of the tree, the bark, bast and cambium are dead, further down only parts of the bark outside the cambium, so that the last can form bast and young wood during summer. "The white, tender bast then can be easily loosened from the sappy wood as in healthy trees. The dead bark zone joined the newly formed bast and, outside this, the green bark was still living. Many strips of dead tissue, enclosed by cork, extended through this green bark. Still further down, the dead bast and bark parts were no longer bands, surrounding the trunk, but were divided into strips; finally only dead spots are found and some meters below the tip of the tree, every sign of disease disappeared. The trunk and the roots were perfectly healthy." (Fig. 100.) In the adjoining illustrated cross-section from a spruce, blighted at the tip, the bark is finally killed only on a few places in connected strips extending from the outside inward. Otherwise, in the bark layer, only scattered smaller centres of browned tissue may be found. Since these lie within the living bark, they are enclosed by a layer of white cork. The bast ring seems browned, but broken in different places by healthy tissue.

Fig. 100. Cross-section through a blighted spruce tip; from the Forestry Division of Starnberg. (After v. Tubeuf.)

The correspondence of these charactristics with the changes, described by R. Hartig as *"lightning traces,"* led v. Tubeuf to the opinion that this

1 Beobachtungen über elektrische Erscheinungen im Walde. Naturwiss. Z. f. Land- u. Forstwirtsch. 1905, p. 308.

2 v. Tubeuf, Die Gipfeldürre der Fichten. Naturwiss. Z. f. Land- u. Forstwirtschaft. 1903, No. 1. Continuation ibid. No. 7, 8.

widely distributed tip blight, appearing suddenly in many individuals, must be the result of electricity. The most important point to which the author himself calls attention is that lightning usually strikes below the top, injuring the trunk, but leaving the crown uninjured; in other observed cases whole trees have died, but never the crown alone. In discussing the objections of other pathologists who consider that this blight is due to beetles or leaf rolling caterpillars (*Grapholitha pactolana*)[1], v. Tubeuf emphasizes the fact that the the trees show the characteristic symptoms of disease when the bark beetles are absent, and that these, attracted by the smell of turpentine, appear only secondarily. Some pines and larches behaved like the spruces. In spruces injured by lightning, the dead wood is found in the form of brown strips of bark, surrounded by cork, lying within the otherwise green and fresh bark, and below the dead tops. v. Tubeuf could not find this either in trees which had been broken off, bent or eaten off, nor in others which had been frozen or killed by insects.

Further investigations[2] proved that the anatomical characteristics of top blighted spruces, are identical with those found in trees where lightning had produced extensive injuries. The main support of the theory, however, lies in the fact that v. Tubeuf and Zehnler[3], by means of experimentally produced sparks, were in a position to produce, on the living trunk, external appearances of top-blight as well as all the similar anatomical pathological phenomena, viz., the dead "*bark-eyes*" which are surrounded by a layer of white cork. So long, therefore, as it cannot be proved that other causes produce the same symptoms, we must hold to the fact that the kind of top blight described is a result of electrical discharges. These, in themselves, may be weak, but v. Tubeuf states that in his experiments with deciduous trees, and in his observations in the field, electrical injuries do not radiate far into the healthy tissue. In artificial electrical injury, the leaves died only to a certain point.

In order to facilitate the conception of electrical discharge, v. Tubeuf calls attention to the St. Elmo's fire[4] and has produced this experimentally. He refers in this to earlier experiments by Molisch[5]. Inspired by the observations which Linnaeus' daughter and son had made on the effect of lightning on flowers, he produced a light cluster, i. e., a shiny but quiet electrical equalization.

In v. Tubeuf's experiments, potted plants were insulated by being placed on a ball of wax. The soil was connected by a copper wire with one conductor of an induction machine and a wire was likewise fastened to the ball of the other conductor. As soon as the machine was set in motion the

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1 See Möller in Zeitschr. f. Forst- u. Jagdwesen. 1904, Part 8.

2 v. Tubeuf, Über den anatomisch-pathologischen Befund bei gipfeldürren Nadelhölzern. Naturwiss. Z. f. Land- u. Forstwirtsch. 1903, No. 9, 10, 11.

3 v. Tubeuf u. Zehnder, Über die pathologische Wirkung künstlich erzeugter elektrischer Funkenströme auf Leben u. Gesundheit der Nadelhölzer. Sonderabdruck.

4 v. Tubeuf, Elmsfeuer-Versuche. Naturwiss. Z. f. Land- u. Forstwirtsch. 1905, Part 5.

5 Molisch, Leuchtende Pflanzen. Jena 1904, G. Fischer.

flower pot, together with the plant, was charged. "If the other wire is brought near the plant, a current of the positive and negative electricity is seen which had been separated in the two conductors and then in the two wires. The *positive electricity* flows out in the form of a *light cluster,* the negative appears like little *beads of light on the tips.*" Experiments with spruces and pines proved that a considerable number of needle tips on a plant, negatively charged, gave out the electricity in the form of beads of light when approached by the positively charged wire. If, however, the plant is charged positively, the electricity flows from the tips of the needles *without light*[1].

It was observed in tender plants that if the positively charged wire is held so high above the plant that there were no beads of light to be seen on the edge of the blossoms and that no sparks jumped over, no injuries followed. If this precaution was not observed, after a few minutes the petioles and parts of the sprouts below them began to wilt. These appeared darkly glassy as after frost or injury. It should be deduced from these experiments, that quiet electrical discharges can not call forth a direct injury, but that such an injury is felt at once if a spark discharge takes place.

Differences Between Lightning and Frost Wounds in Conifers.

As yet, in v. Tubeuf's published results of his experiments, there is still lacking an illustration of the anatomic condition of the lightning traces which manifest themselves as eye-like spots in the bark. (See Fig. 100.) Although in the works of Colladon and R. Hartig, mentioned at the beginning of this section, we also find statements as to isolated, ring-like traces of lightning, it still seems to me that further experiments must be made to demonstrate whether such injuries could not be produced by frost. My question has received added force since in deciduous trees I have observed similar phenomena round about bast groups which, lying near the eyes, had been injured by frost.

In order to get reliable comparative material, I begged from v. Tubeuf specimens of his spruce, artificially struck by lightning, and produced frost wounds by exposing a healthy five year old pine (v. Tubeuf had also found characteristic lightning wounds in pines and larches) in May for a night to a temperature of 7°C. below zero in a freezing cylinder. The tree, apparently uninjured when taken from the freezing apparatus, was observed at the end of the year. This delay was necessary in order to give it time to heal over possible inner injuries as must also have taken place with the lightning wounds.

The pine showed inner injuries only in the bark on one side of the base of the trunk; indeed, partly in the form of isolated dead cells with brown swollen contents in the middle of healthy parenchyma; partly in the form

1 Über die Unterschiede in der Wirkung der positiven und negativen Elektrizität. Compare Plowman, Electrotropism of roots. Americ. Journ. Sc. 1904. cit. Bot. Centralbl. 1905, No. 40, p. 342.

of larger dead cell groups which were enclosed by a living parenchyma wall, circular in form; thereby they formed a figure resembling an eye (Fig. 101). In the centre of this eye-like figure frequently a depression was formed (*h*), which was lined by slightly browned, at times almost colorless, cells (*u*). In comparing the pictures, which vary in each section, one became convinced that these cells, enclosing the cavity, corresponded to a resin canal lining and at times had been pushed out like vesicles into this cavity. This was bounded on the outside by a dead bark parenchyma (*p*), with only rarely collapsed cells and usually of natural size, of which the contents and walls

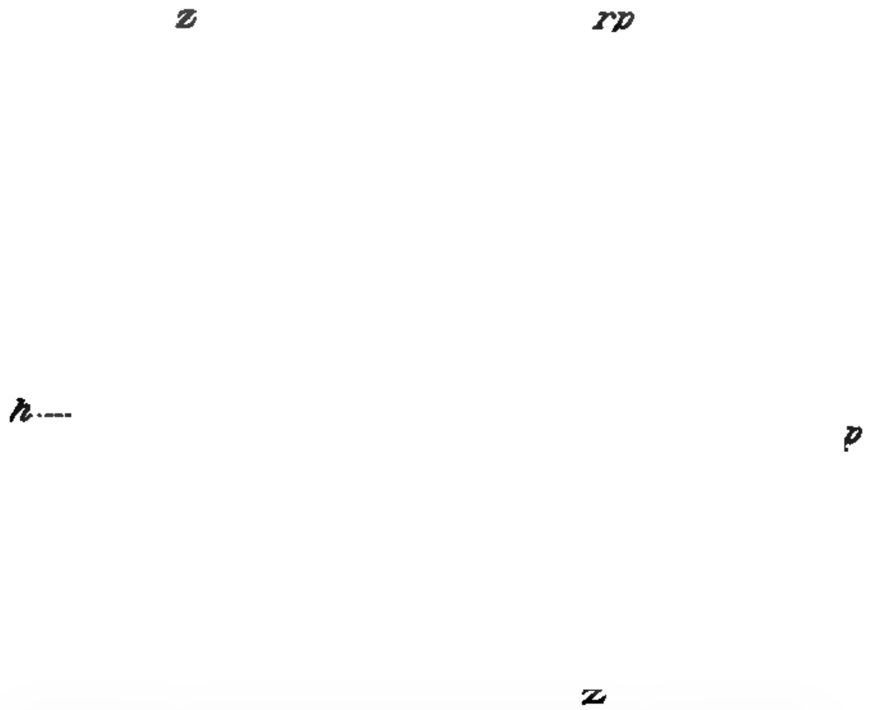

Fig. 101. Pine, artificially frosted. (Orig.)

z Isolated dead bark cells with brown homogeneous contents, *h* cavity in the dead heart of the tissue, *u* slightly colored or almost colorless lining of the central cavity which in structure and composition, exhibits clearly the structure of the lining of a resin canal, *p* brown bark parenchyma cells from the region of the resin canal completely impregnated with resin, *r* parenchyma elongated like plates and containing starch. *rp* normal bark parenchyma.

were impregnated with resin. By clearing the sections, different groups of oxalates could be recognized in the dead parenchyma as well as cells with grains, which should be considered as starch impregnated with resin. This dead tissue was bounded on the outside by the above mentioned circular zone of plate-like cells, which in their arrangement resembled a cork overgrowth when treated with chloriodid of zinc, but gave a cellulose reaction in their walls and were often filled abundantly with starch and small drops of resin (*r*). This overgrowth of the dead tissue centre, which gave the eye-like appearance to the frost wound, often passed over into the normal bark parenchyma (*rp*) which here and there left recognizable traces of starch.

Fig. 102 shows a cross-section through the bark of a small spruce trunk injured by artificial lightning. The trace of lightning (*b*) shows, first of all, a central brown strip-like kernel of swollen parenchyma. This kernel is surrounded by a broad, clear zone (*k*) which consists of radially arranged rows of very thin-walled, nearly empty cells, often containing air.

Toward the outside, this zone adjoins a tissue ring (*kk*) of plate-like cells, rich in cyptoplasm, the walls of which give a cellulose reaction. These cells gradually pass over into the normal bark parenchyma (*rp*) with its large lumina. The resin ducts (*g*) lying outside the trace of lightning but pretty near to it, are, as a rule, uninjured; the living cells at times projecting into the resin ducts are light-walled. This vesicular outpushing of the lining cells is a normal phenomenon; for in branches of healthy spruce in winter, resin canals are often found completely filled by tylose-like enlargements of the lining cells. Resin ducts also occur isolated in the immediate proximity of a trace of lightning in which the cells filling them are changed to brown, swollen, resinous masses.

The dead tissue kernel in the centre of the lightning trace consists frequently only of dead bark parenchyma. Often, however, it can be noticed that some bast groups (*h'*) have participated in this. The fact should be emphasized, that the dead parenchyma cells are often entirely collapsed and dried. In my opinion, the production of the light colored circular zones, composed of thin-walled cells with broad lumina which are found to be actual cork cells and constitute the difference from the frost wound, is due to the drying up of the cells.

I conceive of the production of this difference in the two forms of wounds as follows: The electric spark causes a *rapid drying out* of the dead tissue. Since this, like frost, does not cause any slowly spreading, subsequent death of the adjoining tissue, vigorous cells, capable of reacting, directly bound the dead tissue centres. A reaction to the wound stimulus sets in at once if the vegetative activity makes itself felt in the bark. The parenchyma around the dead tissue responds to the wound stimulus by cell elongation and increase. The cell groups dried by lightning, allow the surrounding cells to elongate greatly. The more rapidly the process takes place, the more material is used up. If this is not present in sufficient amounts only a formation of cork will take place and thus the fact is explained that after the electrical discharge the bark parenchyma surrounding the dried tissue must elongate and divide to fill out the large spaces; then there is a formation of cork.

When frost kills an area of tissue, lying in the bark parenchyma, at first no drying of the tissue takes place. The dead, swollen cells retain their size, and are still turgid. Also the pressure of the dying frost-injured tissue on the healthy surrounding tissue is not essentially increased. The surrounding cells have no incentive whatever to the great elongation and division which were necessary in the drying out of the lightning traces. Therefore, there will appear around the dead centre of the frost wound the

Fig. 102. Spruce, showing traces of artificial lightning. (Orig.)

b central portion of the trace of lightning in the bark parenchyma. *h* group of normal hard bast, *h'* group of bast enclosed by the lightening trace, *k* cork ring, *kk* the cell layer resembling the cork cambium, *g* resin canal in the healthy bark from the normal lining of which some cells have curved outward like vesicles. *gg* resin canal filled with resin. *o* oxalate crystals. *st* bark cells filled with starch. *rp* healthy bark parenchyma. *r* swollen tissue groups in this bark parenchyma, *sch* bark scales.

new structure, produced as a result of the wound stimulus and in the form of a circular zone of scantier and smaller cells. The plastic food material, flowing toward these spots, cannot be longer used for cell increase, since the need has been met. It will therefore be laid down in the form of reserve substances. Hence the noticeable accumulation of starch directly about the frost wound.

As a positive result of the investigation, it should be cited that in conifers a definite difference exists between artifically produced, eye-like wounds due to lightning and to frost. In wounds due to lightning the dead bark tissue dries rapidly and is then surrounded by a porous layer of cork which forms a light colored outer ring. In frost wounds, the dead cells in the interior of the bark parenchyma at first retain their former size. They are enclosed by a circular zone of newly formed cells; these do not develop a porous layer of cork, but rather form a slender parenchyma zone, with narrow lumina, which usually is richer in reserve substances than the normal bark parenchyma. This zone, in a wound due to lightning, is formed next to the cork zone.

These statements are corroborated by von Tubeuf's observation on the differences between wounds due to lightning and to frost. In injuries caused by lightning the ring of dead bark radiates into the healthy tissue in constantly widening bands, while similar phenomena in the injuries due to frost have not been observed in conifers up to the present.

In regard to the theory of the action of lightning, the present observations on the structure determine that the electric spark primarily produces a drying of the tissue.

Injuries to Trees in Cities and Towns.

With the increased use of electricity in cities, there is a serious menace which must be mentioned. Stone's investigations[1] show that the alternating and the direct currents cause injuries by local burning. In dry weather, this is less to be feared, but becomes essentially greater when the bark is damp. The direct currents used by street car lines come under especial consideration here. Besides killing this tissue, the weaker currents also stimulate action. Both conditions should be closely examined. Discharges into the earth during thunder storms are more frequent, according to Stone's observations, than is usually supposed and they explain many injuries in the trees, which often are also mistreated by the inconsiderate cutting out of the branches in order to isolate the wires.

Effect of Spray Lightning on Grapevines.

Among Calladon's[2] numerous observations on the action of lightning, the statement is found that in a vineyard, the upper surface of the soil which had been struck by lightning presented a regular, sharply defined circle, the

[1] Stone, G. E., Injuries to Shade Trees from Electricity. Hatch Exper. Stat. Massachusetts Agric. Coll. Bull. 91. Amherst, 1903. ,

[2] Colladon, Daniel, Effects de la foudre sur les arbres et les plantes ligneuses. Mém. de la soc. de phys. et d'histoire nat. de Genève 1872, p. 548-53.

centre showing the strongest action. The vine leaves showed a number of spots, which at first appeared dark green and after several days turned brick red. In the younger sappy stems, especially the cambium had turned brown, while the wood was uninjured. In the injured tissues, the cell walls remain unchanged, but the protoplasm was contracted and killed. Rathay[1] has described the same observation of the distribution of the effect of lightning on numerous individuals and, after mentioning earlier cases, also refers to the fact that the same phenomenon of the spreading out of the lightning is observed in sheep herds, where likewise several individuals were always hit.

Like Colladon, Rathay also observed that the leaves became red in varieties which showed a red autumnal coloring. All the ends of the branches died back. The process of the red coloration in leaves has already been determined by Wiesner and by me as a result of ringing and bending experiments. Rathay supplemented this by observing that the reddened leaves transpired much less than normally green ones. Leaves reddened after having been struck by the lightning, resembled, in all particulars as yet tested, those which turned red from ringing the branches and actually the injury from lightning resembled in many points mechanical girdling, since here the bark lying outside the cambium was killed. "The cambium of the parts struck by lightning remains alive and develops inside the dead tissue, toward the outside, a callus surrounded by wound cork and, toward the inside, a woodring which is separated from the older wood by a thin brown layer." The grapes on the vine struck by lightning dried up absolutely.

We find in a work by Ravaz and Bonnet[2] different points of importance, showing parallelism between the effect of lightning on grapevines and on conifers. After calling attention to the fact that a place struck by lightning which was planted with 50 to 100 vines, showed that the strongest plants were much injured, it should be emphasized that, after being struck by lightning on the 20th of May, the tips of the shoots turned down toward the ground and dried up. The nodes remained green for some time, while the internodes looked almost scalded. The phenomenon of disease gradually decreased toward the bottom. Below the dried tips, the pith was torn in the injured young shoots and pressed against the woodring. The roots remained uninjured. Some weeks after having been struck, the injured internodes appeared a reddish brown, shrivelled and cracked longitudinally. The tears showed a scar tissue. The intermediary nodes were strikingly swollen. Where the tips had not been struck, the branches grew further, but had very short internodes. The young wood tissue appeared brown and its cells empty and with unthickened walls. The injured parts of the bark were enclosed by cork so as to form island-like structures (compare

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[1] Rathay, Emerich. Über eine merkwürdige durch den Blitz an **Vitis vinifera** hervorgerufene Erscheinung. Denkschr. d. math.-naturwiss. Klasse d. kais. Akad. d. Wissensch. Wien 1891. Extensive bibliography here.

[2] Ravaz, L. et Bonnet, Effects de la foudre sur la vigne. Extr. des annales de l'école nationale d'agricult. de Montpellier; cit. Bot. Jahresb. 1900, II, p. 417.

Fig. 102). The cambium formed first an irregular tissue, which gradually passed over into normal wood (compare Fig. 99).

From these statements we arrive at the conclusion that *lightning* (like frost) also causes considerable injury by *mechanical action* and, in fact, as a result of sudden excessive differences in tension. The trunk reacts in a different degree according to its age when injured by lightning. Where the bark is not injured to its whole extent, the dead places are surrounded by a cork layer. If the young wood is not entirely killed but only compressed or torn, a parenchyma wood develops later, which slowly passes over into normal wood, so that false annual rings can be produced. All phenomena spread out gradually from the base of the trunk; that is, they finally disappear.

It is a matter of course that micro-organisms infest all wounds due to lightning and it is easily comprehensible that these cases have been described as parasitic diseases. An example is offered by "Gelivure" of the grape which has been described as bacteriosis, but, according to Ravaz and Bonnet, is nothing less than a wound caused by lightning and infested by bacteria[1].

Spray Lightning on Fields and Meadows.

Steglich[2] observed one July a *potato* field which had been struck by lightning. The lightning hit in two places and the plants became yellow and died; the stems seemed cracked open and perforated so that the walls of the wound appeared torn.

v. Seelhorst[3] describes injuries to *beets* from lightning. In one case the place struck formed a circle about 15 m. in diameter. In the middle of the circle the *beets* were all killed. The leaves on the plants near the periphery were wilted and discolored. Often individual specimens slightly injured, stood between plants greatly injured. At times small cavities were noticeable in the beet, especially in the head. In other cases, practical workers speak of discoloration and weakening of the heads of the beets and similar phenomena; nevertheless, secondary parasitic influence may have made itself felt here. Colladon[4] also makes a report of a beet field struck by lightning. The leaves of injured plants were colored red, shrivelled or torn in places and the edges partially dried. In one potato field the majority of the plants in the upthrown soil were found to be healthy; only in one place did the base of the potato stem seem torn and burned. In the place struck by lightning on a meadow, with a diameter of 6 m., the highest thistle tips were killed, while the lower parts and the grass remained healthy, although here and there the earth was found to have been torn up.

To explain the circumstance that the condition of individuals hit on similarly planted bits of land always varies, Rathay cites photographs of

[1] Ravaz, L. et Bonnet, A., Les effets de la foudre et la gelivure. Compt. rend. 1901, I, p. 805.
[2] Jahrb. d. D. Landw.-Ges. 1892.
[3] v. Seelhorst, Rübenbeschädigung durch Blitz. D. Landw. Presse 1904, p. 515.
[4] Loc. cit., p. 555.

lightning showing that it usually is not a simple discharge between two points, but is *scattered and ends in many points.* In addition to this, it should be emphasized that when grapevines are trained on wires, these spread the injurious effect over a greater area.

v. Bezold's[1] statements that, according to the statistics of the Fire Insurance Company in Bavaria, the danger from lightning had increased threefold between 1833 and 1882, are especially significant. The extensive removal of forests and marsh drainage and the rapid increase of rails and electric wire conductors are supposed to play a part in this.

Disadvantages in Electro-Culture.

The attempts to use electricity directly in plant cultivation have followed three lines. In the first place, it was desired to increase the assimilatory activity by illuminating with electric light; in the second place it has been attempted to let an electric current pass through the earth by sinking two metal discs in the soil connected with some source of current; in the third place, an attempt was made to cause the current to pass directly through the plant (or tree).

As yet the results have been very contradictory, so that no decision has been reached. Great hope is set often on the influence of a *silent electric discharge.* This takes place when, for example, a net of wires is laid over a field without touching the soil and one pole of an electrifying machine is connected with the wire and the other with the soil. In such cases the plants act as conductors and through them, by means of the silent electric discharge, the electricity will stream out from the tip of the cultivated plants. Such a current must actually take place constantly in nature, since the soil exhibits an electric charge differing from that in the layers of air lying above it. The best known experiments are those of Lemström[2] and Pringsheim[3]. Older works on experiments, in which the electrical current is conducted through the soil, had been collected and enlarged by Wollny[4].

The results of Pringsheim's experiments, in which the electricity was produced by a static electric machine, sound extremely favorable, since in potatoes, sugar beets, beans and strawberries a quantitatively and qualitatively better yield is obtained. Since, however, many unfavorable experiences exist, this field, for the present, should not be considered any further, as it is not sufficiently cleared up. However, Löwenherz'[5] work must be mentioned because it has been carried through with scientific exactness and opens up new points of view.

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[1] v. Bezold, W., Über zündende Blitze im Königreich Bayern während des Zeitraums 1833 bis 1882. Abh. d. Kgl. Bayer. Akad. d. Wiss. II. Cl., Vol. XV.

[2] Lemström, Elektrokultur. Translated by O. Pringsheim. Berlin 1902. W. Junk.

[3] Pringsheim, Otto. Neue Elektrokulturversuche. Österr. landw. Wochenbl 1904, No. 24; cit. Centralbl. f. Agrikulturch. 1905, Part 6.

[4] Forschungen auf dem Gebiete der Agrikulturphysik. Vol. II, 1888, p. 88.

[5] Löwenherz, Richard, Versuche über Elektrokultur. Z. f. Pflanzenkrankh. 1905, p. 137.

The experiments were made with Chevalier barley; a direct current of electricity was used which was conducted through the soil. The grains were very carefully sown, so that in half the experimental pots the seeds lay with their long axes parallel to the direction of the current, thus being traversed longitudinally by the current, while in the other pots, the grains were laid at right angles to the direction of the current. It was thus found that the different position of the grain in relation to the direction of the current resulted in a very unexpectedly great difference in the effect of the electricity.

With the strength of current used (0.015 to 0.030 amperes) an injury in the process of germination was universally noticeable, but it could always be recognized that the grains, which were traversed longitudinally, germinated less well than those through which the stream passed crosswise; yet in the first named series, a difference was perceptible in the grains lying parallel with the direction of the current, inasmuch as those developed the most poorly in which the positive stream entered at the tip of the grain and left at the end where the embryo lies. If the direction of the current was reversed two or three times within the 24 hours, no difference in the results could be produced, but, if the current was changed two times per minute, such a difference became clearly evident. The grains laid perpendicular to the direction of the current sprouted just as well as seed not electrically treated. In those traversed longitudinally by electricity, the disadvantage manifested itself noticeably only in the fact that the grains germinated 12 to 24 hours later. This experiment, which deserves consideration, shows clearly that varied conditions must be taken into consideration in cultivation with electricity

Supplementarily, the endeavor to treat electrically the roots and older wood of grapevines by currents of high voltage should be considered here[1]. At the request of the Imperial Agricultural Association at Moscow, experiments were introduced, incited by reports of combatting Phylloxera by electric currents, in which experimental cases, containing roots and cuttings, were exposed for 10 minutes to an electrical discharge. Some roots were then treated with a spark discharge. It was found that currents of high voltage caused an earlier and more favorable development of the vines. Roots, however, which had been treated directly by being connected with the machine exhibited injuries, for the upper parts did not sprout. Sprouts appeared only on the subsoil nodes.

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[1] From a review of the "Weinlaube" 1904, No. 34; cit. Centralbl, für Agrikulturchemie 1905, p. 394.

CHAPTER XL.

LACK OF HEAT.

A General Survey.

Life Phenomena at Low Temperatures.

The plant is much more dependent on the temperature of the air than on the temperature of the soil. Before the soil can follow the fluctuations in the warmth of the air, this has already awakened plant life and at times brought it to considerable development. The individual parts of the plant naturally do not respond to the fluctuations in the temperature equally quickly. While the warmth of leaves and thin stems, in the shortest possible time, increases or decreases, parallel with the temperature of the air, thick trunks will need considerably longer time, more particularly since all plant tissues are poor conductors of heat. From this last circumstance it is evident that thick trunks are sometimes warmer than the surrounding air, sometimes cooler, and, in fact, are on an average cooler than the air in the daytime and warmer at night. But those parts of the plants which extend into the air are also cooler in the daytime. The cooling down of the leaves comes from their radiation of heat. This will be greater the greater the surface of the part in proportion to its bulk. Evaporation should also be taken into consideration as a further cause; it proceeds at the expense of the warmth of the plant part. These two causes explain the phenomenon that, on bright nights, the thermometer shows a temperature several degrees lower if it stands directly between densely growing plants with thin leaves, such as meadow grass, than is found in the air layer above them. If the temperature of the air itself approaches the freezing point of water, the parts of the plants may be cooled below zero degrees C. by their heat radiation and, as a result, die, or, at least, at times some of their functions are arrested. According to Sach's[1] observations the chloroplasts of the firebean (*Phaseolus multiflorus*) and maise (*Zea Mays*) cannot turn green if the temperature does not rise to at least 6 degrees C. Rape acts in the same

[1] Lehrbuch III, p. 636.

way. The stone pine (*Pinus Pinea*) requires at least 7 degrees C. In Potamogeton, the breaking down of carbon dioxid is found first between 10 to 15 degrees C.; on the other hand, in Vallisneria even above 6 degrees C., and in the leaves of the larch at 0.5 to 2.5 degrees C., and in meadow grass at 1.5 to 3.5 degrees C. The movement of the leaves of the sensitive plant (*Mimosa pudica*) first occurs when the temperature of the surrounding air exceeds 15 degrees.

The difference in the amount of heat required by different plants is shown best by the observations made *on the germination of seeds in ice.* Uloth[1] found, for example, that seeds of wheat and maple (*Acer platanoides*) germinated in ice and bored their way deep into the ice, which they melted by the heat developed during germination. The fine lateral roots of the wheat had traversed ice pieces one-eighth of a meter in thickness. Later experiments[2] showed the same observer that several of the Cruciferae (*Lapidium ruderale* and *L. sativum, Sinapis alba* and *Brassica Napus*), oats, barley and rye, as well as other grasses, had germinated in large percentages. In barley and oats the percentage of germination, however, was noticeably less than in wheat and rye. Of the Papilionaceae, 80 per cent. of the peas had germinated in the ice-cellar and 12 per cent. of the lentils; 60 per cent. of sown parsley seeds showed germination. Incited by these observations, Haberlandt[3] later undertook further experiments with sowing the common agricultural seeds in cases which were kept constantly at a temperature of zero degrees to 1 degree C. by means of ice. After a month and a half, rye, hemp (*Camelina sativa*), red clover, alfalfa, vetches, peas, and bastard clover showed the beginnings of germination. After four months, however, a further development of the little roots could be proved only for mustard, camelina (or gold of pleasure), bastard clover, red clover and alfalfa, while wheat, barley, oats, ray grass, buckwheat, beets, rape, poppy, white clover, beans, etc., did not reach germination. Of all the plants, alfalfa had strikingly proved most favorable.

These results, in regard to grain varieties, stand in very marked contradiction to Uloth's conclusions and also to the results of experiments which Hellriegel[4] has published. Of all the plants tested, winter rye was proved decidedly to require the least heat. With an almost constant temperature of 0 degrees C. (within the six weeks period of the experiments the temperature only a few times slightly exceeded this, reaching 1 degree C.), this plant developed its leaf and root apparatus perfectly normally. Winter wheat was proved to need somewhat more heat because of the small size of its germinating plants, and, agreeing with Uloth's results, to a still greater degree, barley and oats, which at 0 degrees C., only slightly developed their rootlets, while unable to force the leaf cone out of the grain. At

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1 Fühling's Neue landwirtsch. Z. 1871, p. 875.

2 Flora 1875, p. 266.

3 Wissenschaftl. praktische Untersuchungen auf d. Gebiete d. Pflanzenbaues. Wien 1875, I, p. 109ff., 117.

4 Beiträge zu den naturwissenschaftl. Grundlagen des Ackerbaues. Braunschweig, Vieweg 1883, p. 284-304.

2 degrees C., however, the elongation was quite perfect. Maize had not changed at 5 degrees C. and even at 8.7 degrees C. germinated very slowly and imperfectly. Vetches and rape seed had germinated at o degrees and exhibited a development of the seed leaves worth mentioning, while peas in greater numbers, and lupins and beans in smaller amounts, had elongated the root body, to be sure, but had not developed the aerial axillary part. Of seeds which had germinated at 2 degrees C., flax was more sensitive than rape seed, which germinated at approximately o degrees, but did not advance developmentally or show growth worth mentioning until given a noticeably higher temperature (8.7 degrees C.). Peas and clover were found to stand next to vetches. They put forth a root and leaf at an average temperature of 2 degrees C., while beans and lupins needed at least 3 degrees C. for this. Asparagus developed slowly at 2 degrees C. For the carrot, approximately 3 degrees seemed to be necessary for germination, and for the beet root about 5 degrees C. was needed.

It is not necessary to state here in detail that naturally the length of time of germination increases in proportion to the amount of temperature variation from the optimum of germination, but attention might be called to the fact that such germination experiments with the lowest possible temperature could lead to the growing of *varieties hardy to frost*. In all the seeding experiments uneven germination is found. It may be possible that those seeds which have first germinated at such low temperatures give plants which have a lesser need of heat for all their life processes than do other individuals of the same groups.

Kirchner's experiments[1] show that not only the initial stages of germination can take place normally at such low temperatures but also that a further growth in length is made possible. Kirchner found mustard, rye, wheat, peas and hemp growing, as seedlings, for some time at temperatures which lay but little above o degrees C. To be sure, plants with a greater need of heat still show some growth in length when carried over into a low temperature; but this growth can be explained only as the gradual dying out of the oscillations of the energy of growth obtained under earlier, more favorable conditions.

Kerner[2] has observed with Alpine plants that they can even blossom at o degrees. The melting water trickling into the soil from the snow fields is able so to stimulate the life activity of such plants that the heat produced by their respiration is able to melt the ice crust when it is even 2 to 5 cm. thick, so that the green organs reach the open air (*Soldanello*).

Autumn Coloration.

The coloring of the leaves in the autumn is not always the same for the same variety. It seems that the difference is caused by the habitat of the individual. In general two types can be distinguished; either a perfectly

[1] 4. Vers. deutscher Naturforscher u. Ärzte zu Salzburg, p. 75 d. Berichtes.
[2] Berichte d. naturwissenschaftl.-mediz. Vereins zu Innsbruck, Sitzung vom 15. Mai 1873, cit. Bot. Z. 1873, p. 438.

normal process of yellowing is found, beginning at the edge of the leaf, and followed by the drying of the tissue, toward the centre of the leaf, or the yellowing and drying do not follow parallel, but rather opposite paths, i. e., the process of turning yellow begins at the petioles and the larger veins and advances toward the periphery, so that the edge is colored last of all, while, nevertheless, the first to dry subsequently. I observed the last course especially well in *Acer platanoides,* less constantly in *Acer Pseudoplatanus.* The middle surface showed an uniform brilliant quince yellow, while the peripheral zone was still green. With advanced lowering of the temperature, many leaves showed a turning brown and dying of the outermost edge of the still green part of the leaf periphery, while the yellow, middle field did not yet show any dead places in the tissue.

This case can also occur with Tilia, and in fact usually on one side, since only half of the leaf shows the process. Nevertheless in the linden, the coloration, advancing, from the edge toward the centre, is more frequent. The investigations of numerous cases show that the irregularities of coloration are connected with the irregular dying of the vascular bundles.

The normal autolysis in the autumn sets in when the whole vascular bundle system of the roots has still retained its functioning and the dying back only begins at the finest ends of the nerves at the edge of the leaf. Then the leaf discolors and dries first along the edge; the discoloration advances gradually in the portions of the leaf between the smaller veins and finally also between the larger ones toward the midrib and the petiole. If, on the other hand, the functioning of the ducts is prematurely destroyed in the branch or in the petioles, which can be perceived from the browning of the vascular bundles, then the discoloration begins at the petiole, or the larger veins, and extends irregularly toward the periphery.

The course of the dying back, due to continued summer drought, resembles the normal autumnal autolysis, inasmuch as the parts of the leaf receiving the least amount of water are the first to discolor. Besides the drying of the leaf edges, however, that of the middle region of the larger intercostal fields becomes more noticeable here, because these lie fartherest from the strongly developed conducting strands; thus especially great demands are made upon them because of excess of light and heat.

The autumn coloring begins with a change of the chlorophyll often accompanied by the appearance of a red coloring matter. At first a change in the position of the chloroplasts is noticed, and a tendency to unite. I found in the spruce that the individual chloroplasts form radiating processes which unite with those of the adjacent ones. The red coloration is conditioned by the presence of ferments and related bodies. Many evergreen plants turn a dirty brownish green. According to Kraus[1] this coloring is produced as follows: fine grained protoplasmic masses, colored a bright reddish green to copper red, occur in the palisade parenchyma in place of

[1] Kraus, Über die winterliche Färbung immergrüner Gewächse. Sitzungsber. d. phys.-med. Soc. Erlangen; cit. in Oekonomische Forstchritte 1872, Nos. 1 u. 2.

the disappearing chloroplasts. The further the cells of the leaf flesh are separated from the brown upper surface, the more transitions are noticed from these reddened cytoplasmic masses to the normal chloroplasts.

All these changed tissues may, in many cases, be brought back to the normal color, if cut branches are brought into a warm place. In this, however, the intensity of the light is not increased, and this may explain why only a lowering of the temperature should, in general, be considered as the cause of the autumn coloring. A further proof lies in the fact that in the autumn natural ripening only the ripened places, i. e., the places most cooled down by heat radiation, change their color, while the parts inside the top of the tree and covered by the outer leaves, show no change.

In regard to the change in the coloring matter of the chlorophyll, it has been proved by Frank[1] and Wiesner[2] that the chlorophyll passes over into a substance which Pringsheim called *"Hypochlorin"*[3]. This is an oily body, usually dark colored, which is produced from chloroplasts by the action of anorganic and organic acids and finally crystallizes into needles or whip-like brown crystals. Tschirch[4] has proved that this hypochlorin is identical with the "Chlorophyllan" of Hoppe-Seyler and that it should be considered as the first product of the oxidation of the chlorophyll (and in fact of only one part of the raw chlorophyll, viz., the cyanophyll of G. Kraus). This product is formed of itself if a chlorophyll solution is left standing for some time[5].

Tschirch found that the formation of chlorophyllan or hypochlorin, increasing according to the amount of acid, could be proved (tytrimetrically, by means of normal alkali) in the parts of the plants. Besides water plants, there may be only a few plants, the cell sap of which does not have a marked acid reaction. In genera which contain little acid, the formation of the chlorophyllan will be small and the extract made from this will have to stand some time, while in strongly acid plants (Aesculus, Rumex) the oxidation proceeds so fast of itself that no purely green extract can be made, since it at once exhibits the peculiarities of the modified chlorophyll and, even when chilled, deposits chlorophyllan.

It is worth mentioning, for our consideration, that according to Tschirch even carbon dioxid is able to change the chlorophyll into chlorophyllan. Also the tannic substances with which the red coloring matter is certainly related, will have to be reckoned among those bodies with an acid reaction which attack the chloroplasts. It is thus a question whence it comes that this discoloring influence of the acid cell sap makes itself felt in the chloroplasts only in the autumn. This can be explained either because in the course of the summer so little free acid is available in proportion to the rest of the

1 Sitzungsber. d. Bot. Ver. d. Prov. Brandenburg XXIII, v. 24. Feb. 1882.
2 Bemerk. über d. Natur d. Hypochlorins. Bot. Centralbl. 1882, Vol. X, p. 260.
3 Untersuchungen über Lichtwirkung. Pringsheims Jahrbücher 1880, Vol. XII.
4 Sitzungsber. d. Bot. Ver. d. Prov. Brandenburg XXIII, v. 28. April 1882.
5 Concentrated hydrochloric acid breaks down the chlorophyllan into a body dissolving in hydrochloric acid with a blue color, the "Phyllocyanin" of the authors, and a brown body insoluble in hydrochloric acid, but soluble in ether, the "Xanthin" of C. Kraus. (Tschirch, Untersuchungen über das Chlorophyll III. Ber. d. deutschen Bot. Ges. Vol. I, Parts 3 and 4; cit. Centralbl. 1883, Vol. XIV, No. 25, p. 356.

substances in the leaf cell that the chlorophyll used in the formation of the chlorophyllan is constantly and quickly replaced by the preponderant process of assimilation, in which case usually no yellow coloration of the chlorophyll body is noticeable, or the chlorophyll body may be protected by a substance which does not let the acid through, gradually losing this protection in the autumn. However, both processes might take pace and, according to the above experiments, this is most probable.

Frank and Wiesner refer to the actual presence of an arrangement in the chloroplasts which protects them against the attacks of the acid cell sap. They emphasize that the green grains lie imbedded in protoplasm which is impervious to acids. Tschirch has also mentioned that each chlorophyll grain is surrounded by a colorless cytoplasmic membrane (hyaloplasma-layer) which is especially easily proved in water plants, and in this way possesses a special protection against the acid cell sap.

As the leaf cell approaches the end of its life in the autumn the protoplasm is no longer very abundantly present. But even where it is still more abundant, it undergoes, in the cold of the autumn, a change (which may be overcome by heat), making it permeable to acids. Frank found that the yellow coloration, produced by the action of acid on the chloroplasts, had already occurred when they, together with the nucleus, lay closely imbedded in the cytoplasmic wall layer. Such a change in the diosmotic characteristics of the protoplasm of evergreen trees also makes possible the action of acids. The organic acids increase, however, in the autumnal leaf in this way, making easier leaf coloration.

In regard to the red coloration, C. Kraus[1] has proved that the Brenzcatechin (orthodihydroxbenzine) first found by Gorup-Besanez[2] in woodbine occurs in all leaves which change color in the autumn even (so far as the partial investigation extended) in all leaves still growing vigorously. This substance turns green with ferric chlorid and a beautiful red with vegetable acids. The extracts of the leaves give the reactions of oxyphen acid, on which account the conclusion is pertinent that the red coloring matter in the young leaves and in those which have changed color in the autumn comes from the increased effect of the Brenz catechin, due to the increased action of the acid.

Summarizing all that has been said previously we can *consider the process of the autumnal change of color as a process of oxidation, increased in proportion to the process of assimilation and due to the effect of light.*

This acts very differently on the substances present in the cells of the various plants, so that the chlorophyllan is produced from the chlorophyll coloring matter and the leaf becomes yellow.[3] If the Brenz catechin, which may be produced artificially from carbo-hydrates and probably is

1 Über die Herbstfärbung der Blätter und die Bildung der Pflanzensäuren. Biedermanns Centralbl. 1874, I, p. 126.
2 Annalen der Chemie und Pharmacie 1872, Vol. CLXI, Parts 2 and 3.
3 The chlorophyllan extraction of leaves dead in the autumn shows the same "bandes accidentelles permanentes" as Chantard emphasized earlier (Centralbl. f. Agrikulturchemie 1874, p. 40).

present in opalescing drops, is changed into a red coloring matter by means of an autumnal abundant formation of acid, a reddening and yellowing of the leaves follow. The leaf turns brown, however, if on the other hand, there predominates the formation of brownish yellow masses observed by G. Kraus[1] and Haberlandt[2] with the destruction of the form of chloroplasts, which masses C. Kraus considered as the products of oxidation and humifaction of the carbo-hydrates and which, as I believe, can directly arise from the decomposition of the chloroplasts.

The most frequent, but certainly not the only cause of the red coloration, is the lowering of the temperature, whereby the action of the light becomes relatively excessive. It is not the absolute values of light and heat which are determinative here, but the relative ones, i. e., those coming under consideration in relation to one another. A lowering of the temperature reduces the process of chlorophyll formation, while it sustains in full activity that of oxidation, which, forming Brenz catechin, requires more light[3], and initiates the red coloration. If the activity of the chlorophyll apparatus is increased, i. e., more carbo-hydrates are formed, the accessible oxygen is no longer sufficient for so high a degree of oxidation and the process of red coloration is suppressed. If, however, the work of the chloropyll is artificially retarded by a lack of nutriment and moisture, then the oxygen accessible in the cell can suffice to reoxydize to a high degree the material which has become more scanty; in this case the autumn color occurs even in summer.

As has been mentioned already, I observed in August, with girdling experiments on Crataegus, that the autumn coloring occurred even during the intense heat of summer and that at times it was possible with somewhat more solid leaves to bring the tip of the leaf which had been left on the tree to a bright red autumn change of color by breaking the midrib while the leaf base, lying below the sharp point of breaking, retained its normal deep green color. Besides this, in the course of the summer, we find, in many plants, that the first formed leaves of the annual growth, which have quickly lived out their life, assume their autumnal coloration in the heat of summer (Ampelopsis). Places on young red leaves, which have been covered, remain greener. We will take up these conditions again under "Defoliation due to frost." The winter preparation of evergreen plants will be taken up thoroughly in the section on "Theories as to the Nature of Frost Action."

Frosting and Freezing to Death.

In the literature on this subject, we find different conceptions of the term *"freezing to death."* Death which gradually sets in in a plant because it has not obtained the warmth necessary for carrying through its normal functions has been explained in part as freezing. On the other hand, only

1 Ökonom. Fortschritte 1872. Nos. 1 and 2.
2 Biedermanns Centralbl. 1876, II, p. 48.
3 Batalin. Über die Einwirkung des Lichtes auf die Bildung des roten Pigmentes. Acta Hort. Petrop. VI.

the death which occurs suddenly as a result of a lowering of temperature below the minimum boundary of heat requirement and which is connected, as a rule, with the formation of ice, may be considered as "freezing to death."

We can best overcome this difference in the use of the terms if we consider the first injury, due to a lack of heat, as a *"chronic injury"* and sudden death as an *"acute injury."*

Tender plants from the tropics, which in our greenhouses do not continuously find the heat necessary for all their developmental phases, often furnish examples of chronic injury. Failures in the culture of Indian varieties of Anoectochilus and other tender-leafed orchids, Begonias, Gesneraceae, Marantaceae, etc., are well known. I found their leaves becoming brown-specked, curling and dying if exposed for some time to a temperature of 3 degrees above zero to 5 degrees below zero[1]. In wet, cold years, open ground culture of melons, cucumbers, tobacco and beans became diseased when the lack of heat was prolonged.

In acute injury, one is inclined involuntarily to ascribe it to the formation of ice. That this in itself does not cause death is shown in many cases by our hardy plants, which often are frozen stiff and as brittle as glass and yet continue their growth after the frost has disappeared.

Let us picture to ourselves the effect of the formation of ice in the tissue. If the temperature of the part of the plant has fallen to the freezing point or somewhat below it, small ice crystals are formed on the outside of the cell wall. These crystals, produced at first from the absorption water and later from the imbibition water of the cell wall, become constantly larger, since, at their base, more and more water from the mycellar interstices of the cell wall is changed to ice. Finally, all the fine ice prisms are united into an ice crust. The cell wall has attempted to make up for the loss of water which it has undergone by taking up new amounts from the cell contents.

Thus the protoplasmic body of the cell becomes poor in water, and material changes begin, which finally reach such an intensity that the equilibrium of the different mycellae of the cell wall and of the protoplasm is permanently disturbed. They change in such a way that no more life activity is possible. The cell, killed by frost, thus shows that its walls offered no resistance to the pressure of the cell sap, gradually letting it flow away. In direct contact with the air, this passes over into decomposition and the cell itself collapses. The frozen part of the plant appears wilted and dried, or rapidly decays. The cell sap, passing out of it,—this initiates the decay,—presses through the mycellar interstices and not through any breaks in the cell wall which might have been produced by frost. Indeed in a frozen part of the plant the tissue can be blasted by the ice in different

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[1] Compare also Molisch, Hans, Das Erfrieren der Pflanzen bei Temperaturen über dem Eispunkte. Sep. Sitzungsber. d. K. Akad. d. Wiss. Wien. Mat.-naturw. Klasse, Vol. CV, sec. 1; cit. Z. f. Pflanzenkrankh. 1897, p. 28.

groups and, as frequently observed, the cells of the epidermis can be raised from the underlying parenchyma, while a rupturing of the individual cells, due to the freezing of the water, has as yet been rarely observed. Therefore, the theory formerly generally expressed and now frequently held by practical growers, that the frost kills the plants by rupturing the cells, has been given up as untenable.

In the same plant the same degree of cold can be uninjurious at one time and fatal at another, according to whether *thawing* takes place gradually or suddenly. This latter case may be observed if frozen leaves or herbaceous stems of soft-leaved plants are held in the warm hand. The places of contact frequently become black after thawing and die. We will return to these phenomena in the following.

Rapid and violent *changes in temperature* within a scale above zero degrees C. also did not remain ineffective. Sachs[1] has proved that each rapidly appearing rise or fall of temperature is followed by an increase or decrease of the rate of growth. While de Vries could observe no disadvantageous results from such fluctuations, I found a dropping of the leaves in the most extreme cases, especially if the fluctuations took place in a scale which began several degrees under zero and rose considerably above zero. The same plants in fact die if a change of temperature is repeated several times within a short period, as shown by Göppert's experiments[2]. Milkweed (*Euphorbia Lathyris*) was taken from a temperature of 4 degrees C. below zero into a room at 18 degrees C. The leaves, bent backward and against the stem, because of frost, were raised at once and assumed their normal horizontal position. The same process was found in a repetition of the experiments, which took place five times within two days. On the third day the raising of the leaves began to be less and after eight days the plants were dead. Here, therefore, the cause of death was the repeated action of slighter degrees of frost, while out of doors, and uncovered, they could endure 10 to 12 degrees below zero for some time without bad effects. The same experiments gave similar results with many other plants. This explains the observation in general practice that slighter degrees of cold in many places kill plants which, at the same time, in a place with more constant temperature, can endure much greater cold.

Göppert also calls attention to another fact which may serve to explain the frequent contradictions in regard to the fatal action of slighter degrees of frost in those plants which usually defy greater cold. It depends especially upon the conditions under which the plant may find itself at the time, as shown by the experiment with the common groundsel (*Senecio vulgaris*) and meadow grass (*Poa annua*). Pots of these plants, which had already withstood a temperature of 9 degrees below zero, were placed for 15 days in a greenhouse at 12 to 18 degrees C. above zero. After this time they froze at a temperature of 7 degrees below zero, while other examples of the same

1 Lehrbuch d. Bot., 3d ed., p. 638.
2 Über die Wärmeentwicklung in den Pflanzen usw. 1830, p. 62.

varieties, which had remained out of doors during this time, were found absolutely uninjured by rapid thawing. The killed plants had been made more tender by the retention in the greenhouse. Körnicke[1] also comes to the same conclusion in his observations that French varieties of grain, on an average, more often fall victim to frost than the varieties which originate from the provinces of Prussia and Silesia. The longer cultivation in a country with a mild winter has made the varieties less resistant.

Under otherwise equal conditions, Haberlandt[2] found that the seedlings of field beans, field vetches, carrots, barley, peas, rape, poppy, red clover, alfalfa and flax, grown in a greenhouse at 20 to 24 degrees C., were frozen to death even at 6 degrees C. below zero; rye and wheat at 10 to 12 degrees below zero, while plants of the same variety, grown at the same time in a cold frame, died only at 9 to 12 degrees below zero, and rye and wheat only at 20 to 24 degrees C. below zero.

The plants and parts of plants whose growth has entered upon a dormant period, on an average, suffer less and it is well known that dried seeds survive uninjured many degrees below freezing, while they go to pieces in a germinating stage with much slighter frost.

During the vegetative development the susceptibility to frost changes with the different phases of the cell life.

In unfolding apple blossom buds, which had suffered from a spring frost, I found the youngest cells, richest in protoplasm, were not injured, but those somewhat older, in an energetic stage of elongation, had turned brown, while the still older parenchyma cells in turn seemed healthy.

The cases, cited up to the present, show clearly the difficulty in giving definite thermometer degrees as fixed minimum and maximum boundaries for the developmental capacity of any species. Each plant is certainly connected with a definite scale of heat, but *the boundary and optimum values may change, to a certain extent, according to the combination of the remaining vegetative factors,* momentarily present, which earlier contributed to the construction of the individual.

On the other hand, it must be maintained that in spite of all the vegetative conditions, which increase susceptibility to frost, many plants (especially numerous algae, mosses and Alpine plants) never show any damage from frost. We will have to explain this phenomenon by the fact that the need of heat of such plants is so small that the greatest reduction in temperature is generally insufficient to produce those molecular changes in the tissues which would prevent a reassumption of the normal life functions.

Theories as to the Nature of Frost Action.

After discussing the circumstances which modify the freezing of plant parts, we will consider the theories which have been formed as to the nature of frost action.

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1 Annalen d. Landw.; cit. in Neue landw. Zeitung v. Fühling 1871, Part 8, p. 586 ff.

2 Haberlandt, Über die Widerstandsfähigkeit verschiedener Saaten. Wissensch. praktisch. Untersuchungen, Vol. I.

In this, the *phenomena of crippling,* due to chronic action of cold, no longer come under consideration; for these phenomena are primarily normal functions which are only retarded gradually by a lack of heat until life becomes extinct[1]. The matter is quite different in the acute cases where death follows immediately upon the cold.

In the acute frost phenomena, the formation of ice becomes a considerable factor. This does not occur, however, at the point where pure water freezes but only below 0 degrees C., because the cell sap represents a salt solution. Besides this, observations, of which those of Müller-Thurgau[2] especially should be cited, show that ice is produced only after the freezing point has been exceeded to a certain degree, either to *an excessive chilling or supercooling.* As an example of how often the supercooling point lies considerably below the freezing point, a few statements of the above named investigators may serve as examples.

In grapes, the freezing point (G) was found to be at 3.1 degrees C. below zero, the supercooling point (U) at 6.7 to 7.8 degrees C. below zero; in apples and pears, 1.4 to 1.9 degrees C. below zero (G) and 2.1 to 5.1 degrees C. below zero (U); in potatoes 1.0 to 1.6 degrees C. below zero (G) and 2.8 to 5.6 degrees C. below zero (U), etc.

The formation of ice occurs suddenly; therefore, in cases where some supercooling has taken place, there follows a sudden change in temperature. Our hardy plants, which can still grow unimpaired after they have become brittle with ice, show that the formation of ice is fatal only for certain varieties. In other cases, however, it has been observed that parts of plants, under certain conditions, can be cooled down to a still lower temperature and remain alive, while, with lesser cold, but different conditions, they are frozen as soon as the formation of ice has taken place.

This formation of ice, the process of which we have already described thoroughly, is now ascribed by Müller-Thurgau[3] and Molisch[4] to such a withdrawal of water from the cell, that the cell dies on this account. According to this, death from frost would be a *simple process of drying up.* The investigators support their theory by the physical process, that, in freezing swollen colloidal substances, pure water will be crystallized out, and the colloidal substance, thus gradually drying, becomes stiff.

In contrast to the above theory, is the one we hold, that death from frost is no specific process of drying but should be sought in a molecular *irreparable destruction of the protoplasmic structure.* This destruction is expressed mechanically as well as chemically. The destructive temperature is specific for each variety, each individual, each part of the plant and each method of growth of any plant part, but is not directly connected with

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1 Compare Kunisch, H., Über die tötliche Wirkung niederer Temperaturen auf die Pflanzen. Inauguraldissertation. Breslau 1880. — Sachs, Landw. Versuchsstationen 1860, p. 196.
2 Landwirtschaftl. Jahrbücher 1886, p. 490.
3 Loc. cit., . 584.
4 Molische, Über das Erfrieren der Pflanzen. Jena 1897.

the formation of ice, as was evident in the number of plants which, without injury, endure the formation of ice in their tissues. These plants are called "*resistent to ice*" and they freeze only if the parts, which have been frozen stiff, are cooled down below this specific minimum.

This specific minimum is not fixed but rises with the amount of cell sap, i. e., death from cold occurs at a higher temperature and, conversely, a loss of water will cause an increase in resistance to all factors[1] and therefore, with frost, will cause death only at a lower temperature.

Mez[2] adds to these the following observations: Any aqueous solution of a substance must be cooled down below the freezing point of water before ice can be crystallized out. In dilute solutions, as they exist under normal circumstances in cell sap, the lowering of the freezing point is proportionate to the molecular concentration (Raoult's law[3]). Dalton's law in regard to the solution of osmotic substances which contain several substances in solution, holds good here. According to it, the amount that the freezing point is lowered equals the sum of those amounts which each substance would produce of itself.

Since now each cell in the same plant may have a content gradually differing from that of the other cells, the point of minimum cooling of the cell sap will be a constantly changing one. Since the composition of the cell sap within the latitude of the specific limits of all varieties of plants fluctuates according to the nutrition, it is easy to understand that the various individuals possess a different resistance. This also explains the different behavior of dry and juicy parts of plants. The fact that in seeds, which may be dried, death can result also from a removal of water is explained by Müller and Molisch by the assumption that it takes place because of the sudden formation of ice in the supercooled plant, whereby the water is very rapidly removed. Pfeffer[4] opposes this hypothesis and his book contains a thorough treatment of the pertinent literature. Mez's studies, already mentioned, support Pfeffer, for his investigations led to the following results. The fall in temperature, indicating the end of crystallization, did not lie, in any of the objects tested, below 6 degrees C. below zero. (The experiments were made with petioles of Helleborus, Saxifraga and Strelitzia, with leaves of Sempervivum and sprouts of Opuntia, Asparagus, Begonia, Peperomia, etc.).

"But the cell sap, capable of coagulation and not absorbed, stiffens between 0 and 6 degrees C. below zero. Accordingly, at 30 degrees C. below zero, no greater drying of the protoplasm, resulting from the removal of water in the formation of ice, takes place than at 6 degrees C. below zero. A plant which always survives the formation of ice in its tissues, does not

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[1] Pfeffer, Pflanzenphysiologie, 2d ed., p. 315, note.

[2] Mez, Carl, Neue Untersuchungen über das Erfrieren eisbeständiger Pflanzen. Sond. Flora oder Allgem. Bot. Z. 1905, Vol. 94, Part I.

[3] Raoult's law: cit. Nerst, Theoretische Chemie, 4th ed. 1903, p. 152.

[4] See the chapter on "Die Ursachen des Erfrierens" in "Pflanzenphysiologie," II. Vol., 1904, p. 314.

die, therefore, as a result of the dying of the protoplasts, but of a cooling down below the specific minimum."

We find in this a confirmation of our earlier standpoint, viz., no simple process of crystallizing out the water is caused by the action of the cold but a material disassociation. This action of the cold makes the life functions impossible. Besides these essentially mechanical processes, however, chemical decomposition often plays a part. This will be initiated sometimes by too great cooling, sometimes without it. Not every plant needs to be first cooled down in order to freeze, but it probably freezes more rapidly, i. e., is cooled down to a sub-minimum temperature, if the freezing occurs in association with supercooling. At least this is shown by Mez's experiments with pieces from the stem of *Impatiens parviflora*. We learn from these experiments how very much the supercooling depends upon the constitution of the cell sap. Gases, dissolved air, hinder or decrease supercooling just as do emulsified oil, gum or plant mucilage. It is also found that pruned plant parts, cooled down in water, always freeze without any further reduction of temperature or, at least, without an essential one. It happens that plant stems, standing partially in water, are found to be frozen as far back as they extend into the air. Molisch tested the question experimentally by letting branches of *Tradescantia zebrina* lie half in water. During the night a temperature of 5 degrees C. below zero acted upon them. After a slow thawing in a cool room, the half of the sprouts which had been left in the air were found to be frozen, while the lower half, sticking in the ice, remained uninjured. The upper half, surrounded by air, will have been cooled down rapidly by supercooling and is thereby frozen. On the other hand, as far as the plants stood in water, the cooling down takes place slowly on account of the high specific warmth of the water, and the supercooling will be hindered by the freezing water about the stem as well as by the ice in the tissues above the water, which have been frozen.

An observation made by Müller-Thurgau, that in a heap of beets, the outer frozen roots protect the inner ones from freezing, calls attention to the specially *favorable influence of the formation of ice*. This point is emphasized by Mez, since he says in general that the transformation of the cell sap into a solid aggregate condition forthwith protects from too rapid radiation the energy still retained in the plant. The conducting of heat is very much lower in ice than in water in which the warmth is distributed by currents.

The danger of freezing, i. e., the lowering of the temperature to the specific death-dealing minimum, can in part be promoted by secondary circumstances and in part hindered by them. The decrease lies in the use of the specific heat of water; this will be mentioned again in methods of protection against frost and further in the formation of ice itself, which occurs at zero, or a very little below it, while death sets in only at lower temperatures or finally in a change of the cell sap, since a greater quantity of oil, gum and mucilage acts retardingly.

The increase of the danger of freezing to death exists in all conditions which hasten the appearance of a fatal supercooling.

Thus, for example, the anatomical structure of the individual, depending upon the vigor of nutrition, can influence this. In very luxuriant growth, the lumina of the cells and ducts are wider and the intercellular spaces larger. However, the wider the duct, the more the lowering of the freezing point is suppressed by capillarity. We find this fact emphasized by Bruijning[1]. He found that the extract of Taxus leaves, in narrow capillary tubes, has a freezing point of 8.8 degrees C. below zero, while the same extract in open reagent glasses freezes at 1.3 degrees below zero.

Besides the greater amount of water in the tissues, the constitution of the air (amount of humidity contained) and its movement come under consideration. In the later connection, attention should be called to the widespread discovery that, in protected positions (in narrow valleys, fields surrounded by woods, etc.) plants freeze which would remain uninjured in regions accessible to the wind.

In order to explain this circumstance, we will have to recall the fact that air in motion increases evaporation and thus concentrates the cell sap. With stronger evaporation the formation of ice will occur more quickly, whereby supercooling will be avoided, and, at the same time, protection of the remaining heat in the tissue will be brought about.

In its prevention of supercooling by the superimposed ice, may be found the advantage of the "open furrow" for winter grain; it retains snow much longer.

Fog will also act as a protection. We find a recent example of this in the observations made by Thomas[2], who, in Thuringia, found that the foliage of young beeches, on the heights covered with fogs was uninjured, while in the valleys it was brown and wilted as a result of frost. In this case, an evident boundary line could be found. In mountain forests, the covering of clouds is a protection against frost which one should not underestimate.

We will now turn once again to the fact that in many cases a *rapid thawing* of frozen plant parts can bring about death, while a slow warming does not kill. The correctness of this assertion is often contested. If it is given as an universal rule, it seems inconclusive; but if it is limited to certain cases, it certainly is of value. An older and very instructive example is given by Karsten[3]. A large shipment of tree ferns (Balantium) had to withstand 20 degrees below zero enroute. Some of the plants, when they arrived, were put, in a still frozen condition, into a warm place and were killed, while almost all of those first thawed in cold water and then taken

[1] Bruijning, F. F., Zur Kenntnis der Ursache des Frostschaden. Sond. Wollny's Forschungen auf dem Gebiete d. Agrikulturphys. 1896; cit. Centralbl. f. Agrikulturchemie 1898, p. 173.

[2] Thomas, Fr., Scharfe Horizontalgrenze der Frostwirkung an Buchen. Thüringer Monatsblätter 1904, 12. Jahrg., No. 1.

[3] Über die Wirkung plötzlicher bedeutender Temperaturänderung usw. Bot. Z. 1861, No. 40.

into a cold place, remained alive. From this, it is evident that the rapid thawing and not the frost is the cause of death.

Müller-Thurgau has stated of ripe fruit and Molisch of the leaf of *Agava americana,* that these objects can be kept alive after moderate freezing, if thawed very slowly, but that they die when thawed rapidly.

I pressed the surfaces of the frozen leaves of herbaceous Cinerarias between my finger tips. The plants, left in their places of growth, showed, after thawing, that only the places pressed with the fingers were killed. According to the discoveries of gardeners, it is only the tender-leaved, juicy spring blossoming plants, grown in greenhouses (Cinerarias, herbaceous Calceolarias, etc.), which, after a night of freezing, can be rescued by the longest possible retardation of the thawing.

In plants perfectly resistant to ice, however, the rate of freezing and thawing seems to have but little influence on life.

In explanation of the matter, two points should be taken into consideration. First, in rapid thawing, the same processes will be enacted which occur, for example, in the evaporation of fluid carbon dioxid whereby the formation of solid carbon dioxid takes place, as is well known. In rapid thawing, the warmth necessary for melting will be removed, not only from the surrounding air, but also from the deeper layers of this part of the plant, which are thereby cooled down still more. In such plants in which the critical point, i. e., the specific minimum, lies close below the freezing point, this removal of heat, increased by rapid thawing, can cause death.

The second point to be taken into consideration is that the cell wall, from which ice has been crystallized, cannot possibly soak up the great amounts of water which are produced suddenly by rapid thawing. The water remains in the intercellular spaces and evaporates there while the cell of the leaf is not able to regain the necessary turgid condition. From this comes the gardening method of protecting from the rising sun all plants which have suffered from late frosts.

Let us consider finally the natural processes of the autumnal changes of material from the standpoint of Mez's theory as here discussed. When the plants prepare for winter, they collect the greatest possible amounts of reserve substances and reach the maximum at different times, according to their individuality. In *Pinus austriaca,* for example, Leclerc du Sablon[1] found this maximum in May, but in the spindle tree (Evonymous Europeus), which sends out its shoots earlier, he found it in March; in deciduous trees the maximum is reached in the fall. In evergreen plants, the reserve carbo-hydrates remain abundant in the leaves[2]. Their activity seems reduced to a minimum, since their stomata are closed permanently.

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[1] Leclerc du Sablon, Über die Reservekohlehydrate der Bäume mit ausdauernden Blättern. Compt. rend. 1905, p. 1608; cit. Centralbl. f. Agriculturchemie 1906, p. 322. — Fabricius, L., Untersuchungen über Stärke- und Fettgehalt der Fichte usw. Naturwiss. Z. f. Land- u. Forstwirtschaft 1905, p. 137.

[2] Simon, Der Bau des Holzkörpers sommer- und wintergrüner Gewächse usw. Ber d. D. Bot. Ges. 1902, p. 229.

These reserve substances are protected so far as is possible against frost. Part of the starch wanders into the protected central portion of the trunk and branches (pith, medullary rays and parenchyma wood), and part is transverted into sugar or occurs instead as a fatty oil. In the needles of Alpine spruces, the substance of the chloroplasts is found to flow away and the cell content in winter forms a homogeneous cytoplasmic mass with abundant oil drops. Lidforss[1] has proved this transformation for all the green cells of evergreen plants; in the spring the starch is reformed.

This removal of solid bodies from the cell with the appearance of winter takes place, according to Mez, as an advantageous arrangement in plants resistant to freezing. He calls the fluid substances *"thermally active,"* for, in crystallization, they set free heat. The solid elements, on the other hand, follow retardingly the temperature of the fluids; they are "thermally passive" and absorb heat, since, with the formation of ice, the change of temperature from the point of supercooling towards zero, they must again give up this heat relatively rapidly. This circumstance acts in such a way that, with the accumulation of solid bodies in the cell, the melting point of the cell sap cannot be reached after supercooling has taken place. A great number of thermally passive elements consequently form a menace for the plant, while the fluid, thermally active bodies are proved advantageous as producers of heat. Profiting by the experiments of A. Fischer[2], we will distinguish between oil trees and starch trees, according to whether they change their starch into oil or let it pass into the interior of their trunks and branches and convert it into sugar in the bark. The fatty oil of oil trees (conifers, birches), which we have learned to recognize from Jonescu as a protection against lightning, besides this peculiarity of preventing supercooling, like sugar, is thermally active, i. e., stores up heat to be given out in crystallization. The trees which transform all their starch into oil, conifers, may be fitted to survive a higher degree of cold than those in which a part of the starch is left free and becomes sugar only in the bark (the majority of deciduous trees). This circumstance surely explains the phenomenon that conifers and birches extend farther up into cold regions.

Disturbance due to Chilling.

Cases occur in potted plants in greenhouses, in which the plants suffer when carried from one house to another, in case they are thus exposed to a temperature below zero degrees at times for only a few minutes. Practical gardeners maintain that the plants have *"taken cold."*

Moebius[3] has studied this statement very recently, and has been able to confirm the above assertion. For example, he took a *Begonia metallica* from a warm house, kept it one or two minutes out of doors in a temperature of 5 degrees C. below zero and then put it again in its former place.

[1] Lidforss, Zur Physiologie und Biologie der wintergrünen Flora. Bot. Centralbl. 1896, p. 33.

[2] Jahrb. f. wiss. Bot. 1891, p. 155, cit. by Pfeffer loc. cit., p. 137.

[3] Möbius, M., Die Erkältung der Pflanzen. Ber. d. D. Bot. Ges. 1907, Vol. XXV pt. 2, p. 67.

Even the same day, he noticed newly produced brown spots on some of the older leaves. Later these leaves got a "glassy, dark appearance, hung down and dried up." The young leaves did not suffer. The same kind of discoloration and wilting phenomena were observed in other similar experiments and are in all essentials the characteristics which have been given by practical growers as a result of taking cold. Moebius emphasized that no formation of ice in the tissues can be concerned here. I can bring proof of this in an experiment which I made with *Begonia argyrostigma.* A pot of this plant was taken from a warm house and put out of doors after the temperature had risen to 0.5 degrees C. Within a short time, I saw glassy spots appear on some leaves.

According to the experimental results given in different places in the present chapter, I perceive in the wilting and glassiness of different leaves, with sharp falls in temperature the results of ***sudden differences in tension*** in the tissue. The contraction of the cells as a result of the excessive cooling will cause, in places, an outpressing of water into the intercellular spaces. Besides this, the difference in the different tissue forms united in the leaf organ makes itself felt. We will refer in this connection to the subsequent section on frost blisters where various elevations of the epidermis and loosenings of the tissue are described.

The practical grower at any rate should keep in mind the fact that, in transporting plants from warm houses, there is a possibility of taking cold, even if plants are exposed only a few minutes to a freezing temperature. Since a sharp change of temperature should be avoided, the wrapping of the pots with cloth or paper must be recommended for all cases.

B. SPECIAL INSTANCES OF FROST ACTION.

TURNING SWEET OF POTATOES.

In the well-known phenomenon, that potatoes turn sweet when subjected to slight degrees of frost, Göppert[1] and Einhof[2] had noticed that individual differences make themselves felt. Under the same conditions only part of the tubers turned sweet and remained soft, while the others became hard. If the potatoes were brought quickly into considerable cold (about 10 degrees) they were frozen, as a whole, without showing any formation of sugar. The turning sweet could not be observed except at temperatures which lay only a little below the freezing point. Müller-Thurgau found that this change set in only in potatoes which had been taken from the soil at least a month earlier. It could not be produced in freshly harvested tubers. Probably similar phenomena led Payen[3] to the conclusion that even before the action of the frost, the tubers, which showed the formation of sugar, might have started to grow again.

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1 Wärmeentwicklung, p. 38.
2 Neues allgem. Journ. f. Chemie. Berlin 1805, p. 473.
3 Cf. Czapek, Fr., Biochemie der Pflanzeen. Fischer, Jena, Part 1, p. 371. Here also notes on older literature.

The fact, established by Einhoff and Göppert, that potatoes freeze with greater degrees of cold without becoming sweet and that those which have become sweet remain soft, is explained simply by Müller-Thurgau's[1] experiments. He found that the potato tuber freezes only at 3 degrees C. below zero. To be sure, its real freezing point lies possibly about 1 degree below zero, but the cell juices must first be cooled down to 2 to 3 degrees below freezing, i. e., be "supercooled," before the first ice crystals can be formed between the cells. Naturally, a lowering of the temperature from zero to 2 degrees below zero retards many life processes. Among these are two which come especially under consideration here; viz., the transversion of the starch into sugar and the utilization of the sugar. It may be assumed that the sugar from the protoplasm of the cell is partly used in respiration, partly during the period of growth in the regeneration of the cytoplasm and the starch reversion. Müller-Thurgau[2] found, in fact, that potatoes which had become sweet after having been kept at a temperature of 20 to 30 degree C. had increased their starch content at the expense of the sugar. This had disappeared; with a lowering of the temperature to 0 degrees and 2 degrees below zero, the process of respiration (and most probably also that of the regeneration of the protoplasm) decreases, while the transversion of the starch into sugar does not fall off so quickly. Consequently, the sugar accumulates in the tuber and becomes noticeable in the flavor. It amounts to about 2.5 per cent. of the fresh substance, yet comparatively wide fluctuations are found in different individuals of the same variety. A higher water content in the tubers favors the turning sweet. This increase of sugar corresponds to the loss of starch yet, according to Czubata's[3] analyses, no corresponding proportion can be proved in the two processes. According to Czubata, a part of the protein passes over from the insoluble into the soluble condition during freezing. Müller assumes that the ferment here concerned increases with the lower temperature.

If potatoes which have become sweet are left for some days in a room with a temperature of more than 10 degrees, respiration increases and the sugar is oxidized, i. e., the potatoes lose their sweetness and in this way again become usable for cooking. Other proposed means, as, for example, the leaching of the tubers with water, did not lead to any results. Besides this, however, it should be emphasized that one need not hesitate to use potatoes for seed which have become sweet. Such potatoes freeze only with a greater degree of cold than non-sweet tubers[4].

I should like to add here supplementarily a statement made to me verbally that in Reinerz a cellar is said to exist in a cave in which potatoes become sweet even without the action of frost. This phenomenon is

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1 Müller-Thurgau, Ein Beitrag zur Kenntnis des Stoffwechsels in stärkehaltigen Pflanzenorganen. Botanisches Centralbl. 1882, No. 6.
2 Landwirtsch. Jahrb. 1883, p. 807.
3 Czubata, Die chemischen Veränderungen der Kartoffee beim Frieren und Faulen. Öster.-Ungar. Brennerei-Zeitung 1879; cit. in Biedermanns Centralbl. 1880, I, p. 472.
4 Müller-Thurgau, Landwirtsch. Jahrb. 1883, p. 826.

ascribed to a strong exhalation of carbon dioxid. I have not been able to prove experimentally an increase of sugar in the tubers, by a two days' retention in a carbon dioxid atmosphere. Nevertheless, it might be possible that some effect would be noticeable after a longer time. The statement gains probability from a work by Bachet[1] and Savelle, according to which, by the use of carbon dioxid with a somewhat higher temperature and greater pressure, starch flour was rapidly turned into dextrine and grape sugar, especially if the process of saccharification was facilitated by the addition of gluten. It can be assumed that, because of an abundant supply of carbon dioxid in the above mentioned case from Reinerz, natural respiration is repressed just as by a lower temperature and the process of sugar formation which, according to Müller, can be proved up to a temperature of 10 degrees has caused its slow accumulation. The production of saccharose during germination after an increase of temperature is proved by Marcacci's[2] experiments with slices of potato which had been dried in the sun and in an oven. In the sprouting tubers, saccharose is found in the young shoots and later in the leaves (probably due to the hydration of starch).

It is evident from the above that the methods of using these potatoes, which in outward appearance are rarely distinguishable from healthy, non-sweet tubers, can in no way be applicable for frozen ones, i. e., those turned to ice. A tuber which has been frozen hard is dead and, in thawing, at once falls victim to a high degree of decomposition. It becomes soft and gives off water, while the cut surface turns brown at once, if not immediately coated with acid. The skin separates quickly from the flesh, like a bladder, with a development of gas. The bark cells beneath the cork layer break apart because of the dissolution of the intercellular substance. The cytoplasm is brown and granular and drawn back from the cell wall; the protein crystalls are dark brown; the cell sap is strongly acid.

The Running to Seed of Beets.

By this name are characterized those specimens of sugar beets and fodder beets which set seed even in the first summer. In some years the phenomenon occurs very frequently and disturbs the harvesting and use of the beet since the root is woodier than in the two-year-old beets. Opinions differ as to the cause of the phenomenon. They take two different points of view; some make the constitution of the seed responsible for this, others, the atmospheric conditions and especially spring frosts. In consideration of the fact that actually in years when late frosts have attacked the young beet plants, unusually many may be found which have run to seed and, supported by Aderhold's experiments with kohlrabi, to be mentioned later, we will give here the present cultural retrogression.

From the abundant literature on sugar beets we will cite only one work, since it reports recent scientific investigations and makes brief references

[1] After Compt. rend 1878; cit. in Biedermanns Centralbl. 1879, p. 544.
[2] Marcacci, A., Sui prodotti della transformazione dell' amido, cit. Bot. Jahresb. 1891, I, p. 47.

to the older experiences. Andrlik and Mysik[1], on the ground of numerous analyses, have come to the conclusion that the weight of the seed-bearing tuber may sometimes be less than that of the normal tuber, at other times greater. The root of the seed-bearing tuber is poorer in potassium, phosphoric acid and sulfuric acid as well as ammonium nitrate and amido-nitrogen. The sap is purer. Of the organic substances formed by the seed-bearing beet, the sugar content amounted to only 45 to 50 per cent.; in the normal beet 54 to 69 per cent. "The greater part of the organic substance, free from sugar, is in the pith, i. e., in the elements forming the solid skeleton of the plant. * * * ." "The pith formation probably takes place at the expense of the sugar."

We perceive that the beet plant has changed its inbred method of growth. Instead of storing, in the first year, only reserve substances in the root and making use of them in the following year for the formation of seed, it at once makes further use of the organic substances gained by the leaf apparatus.

This circumstance points to the fact that the normal process in the cultivated beet, the uninterrupted formation of new leaves, has undergone some disturbance. The growth has ceased for some time, rather the beet has passed through a dormant period which would correspond to the winter rest of a normally ripened tuber. The newly mobilized reserve material is used here for the production of the inflorescence, just as in the normal case, after the arrestment of growth. It is conceivable that the late frosts may call forth such an arrestment. They will incite a greater formation of seed stems, the later in the year they occur and the more the subsequent weather favors inflorescence formation. If, however, the weather, following the frosty night, is especially favorable for the development of foliage, the elongation of the axis, already begun, can stop and the development of the root advance. In large sugar beet fields, as a rule, such seed-bearing beets and similar transitional forms are found. This inclination to the setting of seed can certainly be hereditary in the seed, possibly can be prepared in the seed of normal beets, if not sufficiently matured, i. e., for example, if harvested before it is ripe.

Aderhold[2] has furnished experimental proof of the formation of seed-bearing roots in Kohlrabi, as a result of frost action. He brought seedlings in pots into a freezing chamber for 8 to 10 hours and then placed them out with others which had been exposed to frost. In one experiment, he obtained, for example, two seed-bearing roots from 18 untreated plants, while from the same number of specimens which, for 10 hours in May, had been exposed to a temperature of 2 to 6.5 degrees C. below zero, he had 7 seed-bearing plants. In both cases some Kohlrabi plants later overcame the impetus of frost action and formed a root body.

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1 Schossrübe und normale Rübe. Blätter f. d. Zuckerrübenbau 1905, No. 24, p. 374.

2 Aderhold, R. Über das Schiessen des Kohlrabis. Mitt. d. K. Biolog. Anst, 1906, No. 2, p. 16.

It is well known that, in some years, such premature development of inflorescences occurs often in other plants, which form fleshy, storage organs (celery, carrots, radishes). It is very probable that not only frost action but also other processes of arrestment are effective here.

Frosty Taste in Grapes.

The processes which occur in the turning sweet of potatoes take place also in woody plants. In this connection, Pfeffer[1] mentions Fischer's investigations[2] on the fluctuations between the starch and sugar in the so-called starch trees, such as the linden and birch[3]. When branches are taken in winter from out of doors into a warm room, starch is formed in the bark parenchyma, within a few hours, and, in the cold, can again pass over into sugar. A similar formation of sugar, connected with the decrease of organic acids, is found to occur in grapes after the action of frost.

Even when the main stem of immature clusters had been attacked by frost but was still green and the berries clear, a considerable decrease of acid and increase of the sugar content was found[4]. An investigation on Riesling grapes of the decrease of acids in a plant which had been exposed from October 19 to November 9 to a temperature as low as 5 degrees C. proved an acid reduction of 4 per cent. Half ripe clusters, greatly injured by frost when cut off, showed from October 1 to 11, an acid loss of 4.5 per cent.

The frosty taste, however, does not seem to be due alone to the increase of sugar and decrease of acid, but material compounds may perhaps diffuse from the stems of the grapes which the protoplasm of cells would not have let pass through, if there had been no frost action. Through these changes, the susceptibility of the grapes to the fungus of white rot may be increased, since Viala and Pacottet[5] have shown that this fungus is able to infest only the berries which have a high sugar and a smaller acid content. The behavior of black rot is exactly the reverse.

Changes in the Blossom Organs.

In the action of frost, the permanent processes are sometimes chemical, sometimes mechanical. In the former it is difficult to decide in how far they are initiated by the freezing, or if they begin only with thawing. Thus for example, Göppert[6] has observed in the blossoms of Phajus and Calanthe that they turned blue when frozen. This change in color is explained by the fact that, through the action of the frost, the indicans, which is abundant in the normally colorless cells, especially around the vascular bundles,

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1 Physiologie, 2d edition, I, p. 514.

2 Jahrb. f. d. wiss. Bot. 1891, v. XXII.

3 Über die Periodizität der Stärkezu- und abnahme in den Bäumen. Compare Mer, E. in Bot. Jahresb. 1891, I, p. 46.

4 Biedermanns Centralbl. 1879, I, p. 233.

5 Viala, P. et Pacottet, Sur la culture du black-rot. Compt. rend. 1904, CXXXVIII, p. 306.

6 Über Einwirkung des Frostes auf die Gewächse. Sitzungsber. d. Schles. Ges. f. vaterl. Kultur 1874, cit. Bot. Zeit. 1875, p. 609.

is oxydized to indigo. Prillieux[1] states that this change appears first with thawing. Other statements on the behavior of the coloring matter in blossoms vary as greatly and it can only be said in general that the red coloring matter is one of the most resistant; in fact, according to Göppert[2], who has collected many observations on the color phenomena produced by frost, it can be increased in the leaves and blossoms with slight frost action.

Most frequent, and therefore most important, are the disturbances in the blossoms of our fruit trees due to frost. For all practical purposes, the way the process of discoloration takes its course is immaterial. Scientifically, however, it may be of interest to become more exactly acquainted with the frost action. But since it is impossible to determine in natural spring frosts what are the first effects and what the subsequent changes, I have subjected apple blossoms to artificial frost.

After a blossoming apple branch had been exposed for 2 hours to a temperature of 4 degree C. below zero, the investigation, carried on immediately after the removal of the freezing cylinder, showed that all the petals, and also some places in the leaves, had taken on a glassy consistency.

Even after a few minutes (the air temperature was 11 degrees C.) a flabbiness and a turning brown began in the parts which had become glassy. The brown discoloration of the leaves, therefore, is not the direct effect of the cold but a phenomenon making itself felt first with thawing. The petals, with the natural reddish tinges on the under side, had brown veins and were spotted. The edges began at once to collapse and dry up. A cross-section showed that the discoloration was due less to the turning brown of the cell walls than to that of the cell content, since these excreted reddish yellow to brownish yellow solid masses deposited usually in the longitudinal axis of the cells and resembling carotin. The different cell layers of the petals behaved differently. The excreted yellow masses could be proved to be especially abundant beneath the colorless epidermis which had remained at its natural height. Besides this, the parenchyma cells which accompany the vascular bundles of the fine veins showed these excretions especially distinctly. This latter circumstance caused the venation of the fine petals to appear strikingly brown to the naked eye. With the rapidly advancing process of drying, the cells of the mesophyll collapsed, while the cells of the epidermis retained their natural size.

Fig. 103 shows a part of a petal soon after it had been removed from the freezing cylinder. It shows the leaf still in its natural dimensions, with the large intercellular spaces (*l*) between the very thin walled cells of the flesh and with the unchanged epidermis (*e*). The discoloration, due to the yellowish brown contracted mass of the cell content (*b*), is most intense near the vascular bundles (*g*) and in fact especially so on the under side of the leaf. In the vascular bundle the narrow spiral ducts have turned brown.

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[1] Bot. Zeit. 1871, No. 24.—Bull. de la Soc. bot de France 1872, p. 152.

[2] Kunisch, H. Über die tödliche Wirkung niederer Temperaturen auf die Pflanzen. Inauguraldissertation, p. 29. Breslau 1880.

The browning process took a different course in the stamens. After they had been taken out of the freezing cylinder they remained apparently unchanged, while the petals had already begun to wilt. Only later did the stamens become yellowish brown and the anthers a pale yellow. A cross-section through the stamens showed that the brown coloration was essentially conditioned by the epidermis which is rich in contents. To be sure, in all the tissues, the cell contents seemed contracted into drops or lumps and were brown, but the amount of substances in the inner cells was so scanty that the coloring of the whole tissue remained pale. The spiral ducts of the stamens, like those in the petals, had light brown walls. In the anthers, the discoloration depended likewise on the amount of cell contents. These were most abundant in the connective tissue and this consequently seemed most deeply brown, while the epidermis in the anthers themselves and the underlying fibre cells, arranged like palisades, had only very scanty, solid masses of contents and, therefore, seemed almost colorless. The rem-

Fig. 103. Cross-section of a petal of the apple injured by artificial frost.

nants of the ground tissue near the connective tissue were somewhat darker.

The pistils showed the greatest injuries. They were a deep brown and bent when taken out of the freezing cylinder. At first no collapse of the tissue could be seen anywhere. The papillae of the stigma seemed stiff and filled with brown cytoplasmic contents. As in a fresh condition, they still held fast the somewhat swollen and, therefore, differently formed pollen grains, filled with cloudy, uniform contents. In the pistil, as in the stamens, the peripheral layers were richest in content and, therefore, their contents and walls most deeply colored brown.

Among the mechanical disturbances, tangential holes were observed here and there in the tissue of the pistil as in that of the stamens. They were partly produced by the loosening of the cells from one another, but also by the *tearing* of the cells themselves. The number and size of the holes in the tissue increased towards the bottom of the pubescent pistil, the hairs of which, poor in contents, showed a browning of the walls. Here the tissue at the base of the pistil widened into five diverging, bluntly conical

parenchyma groups, arranged with their tips toward the centre, as the point of transition into the five carpels. Each of these displayed an epidermal covering and a parenchymatous inner flesh. In the cross-section shown in Fig. 104, through the receptacle of the apple we see that the future flesh is already traversed by numerous, regularly arranged vascular bundles (*g*). The receptacle, covered with a firm epidermis (*e*), extends, toward the inner side, into five anchor-like branches (*a*). These are the five ovaries into which the pistil has widened. On their reflexed edges, which in the cross-section look like the flukes of an anchor (*r*), the seed-primordia are formed

Fig. 104. Cross-section through a young receptacle of the apple injured by frost.

in the under part of the receptacle and get their nutrition through the vascular bundles (*ge*). The seed cavities (*sf*) and the cavity left free in the centre (*h*) because the edges of the ovaries have not united, are lined with regular epidermis (*e*). The cells of the epidermis of the axillary side (*br*), as also within the fruit cup, are found to be richest in contents and, therefore, most deeply browned, while the central, at first meristematic part of each ovary is only slightly discolored.

A splitting of the tissue manifesting itself in the appearance of tangential holes (*l*), due to the separation of the collenchymatous layers (*c*)

from the inner flesh of the fruit (*m*) may be seen in the transitional zone from pistil to ovaries, even with a low magnification. It should be emphasized that in this, as in the stamens, a tearing of the cells (*z*) actually takes place, while in the coarser tissues only the usual separation of the different cell layers is formed. These mechanical disturbances which, as we shall see later, are so important in the vegetative organs, have a lesser influence in the blossoming organs. The inflorescences die because of the chemical change in the cell contents and drop more quickly if the tissue splits at the same time. The experimental results correspond to the phenomena after natural spring frosts.

Fig. 105. Primordia of an apple flower bud injured by frost.

The dependence of the susceptibility upon the constitution of the cell sap may be perceived from the adjoining illustration of a young apple blossom severely frosted (Fig. 105). The shading, carried out only on one side in this and other drawings, holds good naturally for both halves. All the shaded parts indicate tissues with intercellular spaces, which clearly contain air. At *r* sugar may be proved by the glycerin reaction. The crosses indicate the regions where metabolism has already advanced so far that abundant calcium oxalate is deposited. The rings (*f*) are intended to indicate the different places turned brown by frost; all the younger, inner parts, rich in cytoplasm, have remained healthy; the dark line is a vascular bundle.

Here we should mention only supplementarily the fact that, besides the acute affects of cold already described, chronic disturbances in the life of the blossoms also occur which concern only the retarding of the normal life processes. The best known example might well be the suppression of the opening of the blossoms in *Crocus vernus* and *Tulipa Gesneriana*. Because

of the low temperature, no sufficiently strong growth of the inner side of the perianth leaves takes place, so that the bending out of these leaves and, therefore, blossoming is suppressed. The blossoms of *Ornithogalum umbellatum, Colchicum autumnale, Adonis vernalis* and others, react similarly but more weakly. The processes in *Mimosa pudica, Oxalis acetosella*, etc., prove that even green leaves act thermostatically because of the influence of lower temperatures. Material on this subject may also be found in the later sections which treat of the mechanical effects of frost.

The Rust Rings in Fruit.

The so-called rust rings appear as the result of slight injuries from frost in young fruits. By this are understood various formations of cork in the skin of the fruit, spreading, especially in the pomaceous fruits, in ring-like zones. In many varieties the appearance of cork-color etchings is a very normal process. Our Reinettes, for example, often possess star-like, small rusty spots. The so-called "netted Reinettes" have linear cork tracings on the outer skin of the fruit and often such cork formations obtain a surface-like extent, as, for example, in the French Reinettes, Parker's gray pippin, in the gray autumn butter pear, the medlar, etc. This condition is morbid only when the phenomenon is very extensive in some years (for example, 1900) on many fruit varieties which otherwise remain smooth and when the formation of the cork covers the greater part of the fruit. The initial stages are found in early youth. It is evident after the appearance of very late May frosts that the contents of some groups of epidermal cells turn brown and the cells begin to die. Beneath such places plate cork is formed, and the dying epidermis becomes somewhat convex. During the swelling of the young, green fruit, the formation of cork advances further into the fruit flesh, producing considerable groups of parallel rows of cells arranged perpendicular to the upper surface. In a special case observed in "Amanli's butter pear" these cells, arranged in rows, appeared to the same extent as those in the epidermal cells; they were found actually suberized, however, only in the peripheral layers while the light-colored, thick walls of the more deeply lying cells gave a cellulose reaction. The greater the new formation, the more the overlying, dying cell layers are separated and the outer surface of the fruit becomes rough and scaly.

In flask-shaped pears the pouchy part of the fruit, bearing the blossom end, often appears to have rusty grayish scales, while the half toward the stem is smooth and green. In other cases, a broad, cork-colored band is seen near the blossom end, etc. At times with this splitting of the waxy covering and dying of the epidermal cells is connected the development of the newly produced underlying tissue into stone cells. These appear later in circular aggregations on the outer surface of the fruit, so that the conditions are produced which we have described as "Lithiasis" (p. 170). ("Diel's butter pear," "Good Louise of Avranches"). Since such changes are usually

found on one side the growth of this cork-color side, containing the stone cells, is often retarded, thus producing deformed fruit.

After I had succeeded in causing a splitting of the cuticle in tough leaves by the action of artificial frost, I did not hesitate to trace the injuries in the wax coat of young fruit to frost action, more particularly the formation of such "rust rings" as had been observed only in years with late frosts. The pears, which are susceptible to frost, suffer most abundantly and greatly, in fact usually on one side and at a certain height on the tree.

The Behavior of Older Foliage With Acute Frost Action.

During frost, changes in the chlorophyll grains are noticeable inasmuch as they usually round up into lumps in the cells which have become poor in sap. A chemical change of the chlorophyll coloring matter, due to the frost alone, is not assumed by the majority of investigators, so far as found in statements concerning frozen chlorophyll solutions. Wiesner found[1] no difference in a chlorophyll solution in olive oil exposed to a temperature of 30 degrees C. below zero. On the other hand Kunisch[2] states that the alcoholic extract of chlorophyll from hyacinth leaves, frozen at 7 degrees below zero, was found to differ from that of leaves which had not been frozen. Often dull whitish spots are found in frozen leaves which can arise from ice accumulations crystallized out into the intercellular spaces. Hoffmann found in Ceratonia, Laurus and Camphora, a vesicular raising of the epidermis and called it a "frost blister[3]. In heavy frost, the leaves which have been frozen through become as brittle as glass and transparent. When such leaves are thawed, the change in color depends upon whether the protoplasm of the cells has been killed or not. If it is dead, it becomes permeable to acids in the cell; these penetrate to the chlorophyll grains, and cause their decomposition (the formation of chlorophyllan): the cytoplasm turns brown; the cell sap exudes rapidly; the leaf dries into a brittle, brown mass. Göppert[4], who describes the various colorations of foliage leaves, also mentions an extremely strong weedy smell in frozen plants. In ferns the odor peculiar to the whole family is retained in frozen and dried specimens in an unusual intensity. In artificially frozen branches of the sweet cherry I noticed a decided odor of bitter almond. These phenomena are the result of the chemical changes which make themselves felt immediately and strongly during thawing. Flückiger[5] has observed a different effect in the frozen leaves of the cherry laurel. During distillation, these gave off an oil differing from that of the fresh leaves and no prussic acid, while leaves covered with ice, but not frozen, gave both substances under normal conditions.

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1 Wiesner, Die natürlichen Erscheinungen zum Schutze des Chlorophylls, etc. Festschrift d. k. k. zoolog.-bot. Ges. zu Wien 1876, p. 23.

2 Kunisch, H., Über die tödliche Wirkung niederer Temperaturen auf die Pflanzen. Inauguraldissertation. Breslau 1880.

3 Kunisch, loc. cit. p. 22.

4 Göppert, Über Einwirkung des Frostes auf die Gewächse. Sitzungsb. d. Schles. Ges. f. vaterl. Kultur 1874; cit. Bot. Z. 1875, p. 609.

5 The effect of intense cold on cherry-laurel; cit. Bot. Centralbl. 1880, p. 887.

It is important to refer here to the behavior of the mineral substances in leaves killed by frost, because we thus obtain an insight into the loss in substance caused by the destruction of the foliage in spring frosts.

Schroeder's[1] analyses of red beech foliage which a May frost had killed and which, four weeks later, was examined in the dried condition, gave the following: In the frozen foliage, the whole nitrogen content (3.56 per cent.) of the fresh May leaves is found, while in the autumnal leaves, only about 1.33 per cent. remains, so that, therefore, almost three times as much nitrogen is lost for the plant from the loss of the May foliage as in that of the autumnal falling of the leaves. The dry substance gives 3.01 per cent. ash. Of this ash, 22 per cent. was phosphoric acid, i. e., as much as fresh May leaves, while the July leaves possess only 5 per cent. In May leaves about 30 per cent. of potassium was present normally; in frozen ones, however, only 5 per cent. Naturally very little calcium was present in the young foliage (6.78 per cent. in healthy foliage, 4.70 per cent. in frozen foliage); while the vegetating July leaves possessed three times as much (20.34 per cent.) the dead November leaves actually exhibited 37.60 per cent.

In opposition to the opinion that foliage killed by spring frosts remains hanging on the trees, which thus gives its valuable mineral elements time to wander back into the trunk, reference should be made to Ramann's investigations[2]. He proved that the foliage of the oak, spruce and fir, killed by cold, at first possessed the same composition as fresh foliage, when analyzed before a rain, but, during the rain, it underwent a very considerable change. Ramann found that, within 72 hours, water withdrew not less than 19.219 per cent. of the whole ash of red beech leaves and actually 26.46 per cent. of the oak. This easy diffusibility of the ash elements should not be considered to be the result of later decomposition, as is proved by the fact that the greater amount had been leached out in the first 24 hours; viz., in the beech 15.42 per cent.; in the oak, 19.66 per cent. These latter amounts gave in pure ash 11.15 per cent. and of extraction for the trunk, 14.18 per cent. for the oak.

The amount to which loss of the foliage injures the main body is shown in another different work by Schroeder[3] on "The migration of nitrogen and mineral elements during the first development of the spring growth." The exhaustion of phosphoric acid in the trunk during the production of the young growth is the greatest, namely, 46 per cent.; then follows potassium, 32 per cent. of which is used up; nitrogen and magnesium are removed from the trunk up to possibly 26 per cent. Before the end of this period, 12 per cent. calcium and 84 per cent. of the initial amount of silicic acid are added and replace the loss. Of the whole amount of nitrogen, potassium and

[1] Schroeder. Untersuchung erfrorenen Buchenlaubes. Forstchemische u. pflanzenphysiologische Untersuchungen. Part 1, 1878, Dresden, p. 87.
[2] Ramann, Aschenanalysen erfrorener Blätter und Triebe. Bot. Centralbl. 1880, p. 1274.
[3] loc. cit. p. 83.

phosphoric acid wandering into the young growth, possibly one-fifth comes from the trunk, and four-fifths from the root and soil. These figures favor the theory that the root-body, to a still higher degree than the trunk organs, gives up its reserve provision of nitrogen, phosphoric acid and potassium.

Deficient Greening of Younger Leaves.

A special form of the effect of lower temperatures on the coloring of plant bodies is the *remaining yellow of growing organs* due to the lack of temperatures necessary for turning green. Elving[1] found that etiolin was formed at temperatures which were still too low for the formation of chlorophyll in spindling seedlings, which, exposed for a short time to the light, became yellower than those left in the dark. When plants are uncovered in the early spring, numerous examples are found in which the etiolated shoots which had been produced under the cover, in spite of the at times abundant illumination, generally do not lose their yellow color or lose it only slowly and irregularly in spots. The most abundant examples were furnished by garden hyacinths. If these are uncovered too early in the spring and frost surprises the young leaf cones which are not yet green the leaves develop later a normal color but their young tips remain white or yellow.

In the parts which appear yellow, we usually find the chloroplasts formed and arranged normally, i. e., along the free lying parts of the cell walls or those bordering intercellular passages (epistrophe), but the coloring matter is only a more or less intensive yellow. In this stage, all possible transitions, up to the complete absence of the grains in the wholly bleached tip of the leaf, are found; these are not, however, conditions due to dissolution but are arrestment formations. In the whitest parts of the mesophyll, the cells are filled with a watery cell sap which is traversed by cytoplasmic cords, without the deposition of any chlorophyll bodies in the cytoplasmic wall layer. In other cells of the yellowish parts, the differentiation of the contents extends to the primordia of the chloroplasts, but these appear more whitish, more tender, we might say, and at times, cloudier, less dense and less sharply defined. Normally formed, intensively green chloroplasts are finally found in the parts of the leaves which have grown out of the soil after frost action. At times the lack of green is connected with the presence of red coloring matter. Charguerard[2] furnishes an example; he observed in *Phalaris arundinacea picta*, that the young leaf tips, with their well-known white stripes, appeared reddened by frost. The rose red coloring disappeared with warm weather. Schell[3] confirms the appearance of the red coloration with cold. In the spring he placed plants with red-colored, young leaves under three different temperatures and observed that the specimens kept in a room at 15 degrees C. became green within

[1] Arbeiten d. Bot. Instituts zu Würzburg, Vol. II, Part 3; cit. Bot. Centralbl. 1880, p. 835.
[2] Revue horticole. Paris 1874, p. 249.
[3] Botanischer Jahresbericht 1876, p. 717.

18 hours, while those kept at 8.5 degrees C. turned green only after 5 days. The plants left out of doors, with a maximum temperature of about 4 degrees C. became green only after 20 days when the temperature of the air had risen. These observations favor my theory, that the red coloring is conditioned by the preponderance of a process of oxidation, connected with the action of light, over the process of assimilation. With equal amounts of light, a rise in temperature so increases assimilation that the process of turning green preponderates.

To avoid a fixation of the morbid yellowish appearance of leaf tips, bleached by frost, it is advisable to remove the winter covering gradually, or, for the first few days, to spread a light layer of brush over the plants.

Defoliation Due to Frost.

The sudden falling of the foliage during and after the appearance of the first autumnal frost is only one form of the autumnal defoliation which should be designated *death from senility* (in contrast to the cases already described of abnormal defoliation after excessive heat, drought, lack of light, excess of moisture and other causes, producing a sudden loss of function of the organ). The leaf has simply lived out its life. A normal death of this kind has the least disadvantageous results for the trunk which remains alive. From the senile leaf apparatus many plastic as well as important mineral substances gradually wander back into the trunk and are used again in the following period of growth. The retention of abundant amounts of organic structural substances and the leaching of easily soluble nutritive substances by rain are very disadvantageous in leaves which die in a juvenile stage, since these are thus lost to the trunk. But both processes have but little significance when the leaves die of old age. In this case, as has recently been emphasized repeatedly by B. Schultze[1], the assimilation of carbon dioxid may well be proved, up to the last moment, even if naturally with weakened power. Through the preponderance of the processes of decay over those of construction the leaf's supply of easily soluble proteins is especially impoverished. With the increasing thickening and calcification of the membranes, the conducting of new nutritive substances becomes constantly more difficult, so that the demonstrable reduction[2] of nitrogen. phosphoric acid and potassium thus becomes explicable, even if no considerable process of retrogression is accepted.

After all that has been said in earlier sections on the influence of position, soil constitution and weather, it is not necessary to emphasize here the fact that the life period of the leaves can be proved to be very different for the same species and that in this frost also acts on leaves which vary

1 Schultze, B., Studien über die Stoffwandlungen der Blätter von **Acer Negundo** L., 76 Versammlung d. Ges. Deutsch. Naturf.; cit. Centralbl. f. Agrikulturchemie 1906, p. 35.

2 Fruwirth, C. and Zielstoff, W., Die herbstliche Rückwanderung von Stoffen bei der Hopfenpflanze. Landw. Versuchsstat. 1901; cit. Bot. Jahresb. 1901. Part 2, p. 161.

greatly in age. Accordingly the process of leaf fall is not always the same. The most usual case consists in the formation of a tissue zone at the base of the leaf which is a characteristic *abscission layer.* We repeat here the illustration of the autumnal abscission layer in the leaf of *Aesculus Hippocastanum* (*cf.* Fig. 106). The illustration gives a section made longitudinally through the joint at the base of the petiole. *a* is the bark parenchyma of the branch; *b*, the layer of plate-cork cells which remains when the petiole has fallen and thus forms a protection for the bark tissue; *c* indicates the cells at the base of the petiole which at *e* pass over into the firmer parenchyma of the broadened bases of the petioles, provided with abundant accumulations of calcium oxalate. Between *c* and *e* takes place the process of separation, since at *d* the cells round off and begin to separate from one another. If now the leverage of the leaf, moved by the wind, makes itself felt, the petioles break off at the loosened cell layer.

Fig. 106. Autumnal abscission layer of a horse chestnut leaf. (After Dübner-Nobbe.)

The riper the leaf is at the time of the final autumnal frost, the more easily it falls; on this account, the old leaves of the branch are found to be the first ones broken off by the wind in the autumn. The greater the life energy and the quantity of plastic material, the more resistent the youthful leaf seems to frosts which are not killing frosts.

If killing degrees of frost occur in the autumn at a time when the leaf has not yet sufficiently matured its abscission layer, i. e., the tree is still far distant from its dormant period, then the dead foliage remains on the branches over winter (beech and oak). The beeches in which the foliage remains hanging often leaf out later in the spring than do normally matured specimens[1].

At the time of the first night frost, it is found in the early morning, if the frost still lies on the ground and even in windless weather, that, as soon as the sun comes up, the simple leaves of the trees break off and the leaflets of composite leaves fall from the common spindle. v. Mohl[2] found in such

[1] de Candolle, A., in Centralbl. f. Agrikulturchemie 1879, I, p. 159.
[2] Bot. Zeitung 1860, p. 16.

cases that the leaf scars of the fallen leaves, or those just about to be loosened, were covered, in a number of plants, by a thin layer of ice. Paulownia, for example, exhibited an especially thick ice crust. Often the leaves were still connected with their scar only by the ice crystals. These ice crystals had been formed in the abscission layer of the leaves. The columnal structure of the crystals, their cloudiness, produced above the vascular bundles by little air bubbles, and their arrangement, ending sharply with the boundary of the leaf scar, favor the view that no considerable masses of cell sap, which had possibly flowed out, have been frozen but that small particles of water pass through the cell walls exactly at the place where they are observed and are there stiffened to ice.

The formation of ice may often occur very early and thereby cause, when thawing, the fall of leaves which otherwise would have remained for some time on the tree and may even still be green. Besides this action of the ice lamellae, a premature autumnal defoliation may set in because the leaf is partially or entirely frozen; it, therefore, suddenly becomes functionless and is then pushed off.

In autumnal defoliation the loosening of the leaf always takes place in the abscission layer which, according to Wiesner's observations[1], does not always arise from a secondary meristem but is often found also as a remnant of the primary meristem. In other cases of leaf-fall the process of disarticulation can take place in different tissues.

If the process of disarticulation within the layer of separation be considered in general, the following modifications will be found, according to Wiesner[2]. So strong an osmotic pressure can be produced in the cells of the abscission layer that the tissues separate from one another, leaving smooth surfaces. This we find in defoliation which is the result of excess of water even where this excess arises from abundant watering after a long period of dryness. The phenomena of the dropping of the leaves of Azaleas, Ericas and New Holland plants, so well known to gardeners, after the drying of the root ball, belong here, as does also summer defoliation with the occurrence of rains after a long drought.

According to Wiesner, in autumnal defoliation the macerating action of organic acids comes especially under consideration. He assumes that the surfaces of separation, in death from frost, as a result, have an acid reaction, and explains this by the fact that the frost kills the cytoplasm, thereby making it permeable to the acids which occur in the cell content and then act on the membranes. Oxalic acid may play a great part in this. The above-named investigator laid the stems of various plants in a 2.5 per cent. solution of oxalic acid and found that the leaves had loosened within a few days. The stems of plants which form abscission layers at the internodes also disarticulated within a short time.

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[1] Wiesner, Julius, Über Frostlaubfall nebst Bemerkungen über die Mechanik der Blattablösung. Ber. d. D. Bot. Ges. 1905, Part 1, p. 49.

[2] loc. cit. p. 54.

If the leaf surface is injured by frost, but the part of the leaf lying below the abscission layer, i. e., the leaf stump, remains alive, the frozen part of the leaf will dry up, but the leaf base will be found intact and turgid. Between the leaf base and the dried part differences in tension must arise which lead to the loosening of the leaf body.

Experiments made by Prunet[1] show how quickly the parts injured by frost have dried up. A frozen vine branch with four leaves placed in water, evaporated 475 mgr. of water within two hours. In this its loss in weight amounted to 14.46 per cent. Under the same conditions a similar branch, not injured by the cold, evaporated only 132 mgr. of water and, because of the absorption of water which had taken place simultaneously, increased its weight by 0.26 per cent.

Wiesner has also shown experimentally how, in plants which retain their frozen foliage for some time, often for the winter, this may occasionally be based on a rapid drying. He took branches of *Ligustrum ovalifolium* with frozen leaves and placed them in a warm room in such a way that the sprouts could constantly soak up water. After 6 to 12 days, these dropped their leaves while the leaves of shoots not provided with water remained firmly attached. In cases occurring out of doors, where the dead foliage remains in place on the branches, the separation takes place only after the destruction of the tissue. The moldering of the membranes within the abscission layer will gradually advance so that the wind or some other mechanical cause finally brings about the breaking off of the leaf. In these moldering processes micro-organisms will doubtless cooperate.

From what has been said, it is clear that the mechanics of separation in the autumnal senile defoliation, as well as in that due to frost, can often differ even in the same individual, according to the age of the leaves and the existing accessory circumstances. In many plants (grapes), besides the loosening of the whole leaf from the axis, the loosening of the leaf blade from the petiole also occurs. In other disturbances also, this region is especially susceptible and at times manifests its similarity to the base of the petiole through a similar discoloration. For example, in poplars, it can be observed that in the autumn the base and tip of the petiole become red while the remainder is yellow.

The difference in the time when these processes set in in different individuals, and in the same individual at different heights of the various branches, is connected with the physiological age of each leaf. The *younger* this is, the later it falls from the branch, under otherwise equal conditions, as Dingler[2] has determined, by pruning experiments. He observed a greater power of resistance in the young leaves, especially to autumn frosts. The young leaves of *Carpinus Betulus* did not freeze during frost periods,

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1 Prunet, A., Sur les modifications de l'absorption et de la transpiration, qui surviennent dans les plantes atteintes par la geleé. Compt. Rend. d. l'Acad. des Sciences 1892, II, p. 964.

2 Dingler, Hermann, Versuche und Gedanken zum herbstlichen Laubfall. Ber. d. D. Bot. Ges. 1905. Part 9, p. 463.

lasting all day, but older ones were affected and finally died. I found similar conditions in plane trees in which the age of the tree made itself felt in the same way. In street trees, young specimens had been planted between the older trees. Although they did not stand under the protection of the older trees, they still retained their considerably stronger foliage when most of that of the older trees lay on the ground.

Behavior of Beet and Cabbage Plants in Frost.

In storing sugar beets the loss of sugar, which occurs in the heaps because of the respiration of the beet body, can be decreased only by the lowest possible temperature[1]. In sugar beets which have been frozen, a raising of the sugar content was actually found when the water was frozen out. This has been reckoned by Ninger to be 0.39 per cent[2].

The new formation of saccharose which takes place during the process of freezing is no greater than the amount destroyed. Also the amount of nitrogenous substances and the proportion of proteins to non-proteins remains unchanged. So soon, however, as thawing begins, the latter appear to be increased at the expense of the former. The elements of the raw fibers (cellulose and related substances) become more soluble in acids and alkalis and in part also more soluble in water because of the freezing[3]. In this an increase of non-sugar substances is produced in the sap. I observed in frozen beets partial swellings of the membranes which might be explained as a visible expression of the chemical changes in the cellulose. Strohmer and Stift found a striking increase in the acid content.

The large sugar content, produced by the loss of water, and the consequently more concentrated cell sap will, however, retard the actual freezing of the beet body. Besides this, in the storage piles, the outer, frozen tubers will protect the inner ones from freezing. Müller-Thurgau has referred to this especially and Mez[4] has explained it by the fact that the conversion of the cell sap into a solid aggregate condition preserves the energy still present in the cell from too rapid dispersal. The conduction of warmth takes place much more slowly in ice than in water, where the warmth is distributed by radiation.

The statements of market gardeners that brown cabbage (*Brassica oleracea acephala*) obtains its desired sweetness only after frost, may find adequate explanation in the accumulation of sugar due to the low temperature. According to the analyses made by Märker and Pagel[5], an amount of sap equal to 68.66 per cent. of the remnants of the plant may be pressed

[1] Heintz, Atmung der Rübenwurzeln. Zeitschrift d. Ver. f. d. Rübenzuckerindustrie d. deutsch. Reiches 1873, v. XXIII; cit. Bot. Jahresb., I, p. 358.

[2] Bot. Jahresber. 1880, p. 665.

[3] Strohmer, F. und Stift, A., Über den Einfluss des Gefrierens auf die Zusammensetzung der Zuckerrübenwurzel. Österr-Ung. Z. f. Zuckerindustrie und Landwirtsch. 1904. Part 6.

[4] Mez, Carl, Neue Untersuchungen über das Erfrieren eisbeständiger Pflanzen. Sond. Flora od. Allgem. Bot. Zeit. 1905, p. 109.

[5] Märker und Pagel, Über den Einfluss des Frostes auf Kohlpflanzen. Biedermann's Centralbl. 1877, v. XI, p. 263-66.

out from frozen cabbage plants while the same pressure gave only 7.1 per cent. sap in examples which had not been frozen. 100 ccm. of sap contained in

	frozen plants	not frozen plants
Dry substance	7.96 g	4.04 g
Raw Ash	1.63 "	0.97 "
Grape Sugar	4.17 "	1.41 "
Dextrin (?)	0.80 "	0.58 "
Nitrogenous substances	0.80 "	0.51 "
Extractive substances free from nitrogen	0.50 "	0.54 "

This shows that the soluble elements in the sap have undergone a considerable increase and that, in this, grape sugar is especially concerned. Here, therefore, just as great a formation of sugar has been found as in the potato; Schmidt[1] states this to be 21.85 per cent.

Frost Blisters.

Frost blisters are of less significance agriculturally but certainly worthy of consideration scientifically because of the production of mechanical disturbances in the tissues inside the organs which remain alive. These manifest themselves in the appearance of usually small, blister-like places in the epidermis and at times also in the sub-epidermal layers which are raised from the thin-walled parenchyma of the leaf flesh or the tougher parenchyma of the leaf veins. Instead of an extensive description, we will reproduce in Fig. 107 a cross-section[2] of the frost blister on an apple leaf. *O* indicates the upper side, *U*, the under side. *M* is the mid-rib, *s* a larger lateral vein.

In the mid-rib, the crescent-like wood body, with its numerous ducts (*g*), forms the chief part. On the upper side adjoins a thin walled layer of parenchyma (*m*) free from chlorophyll, corresponding to the pith body of the axis. This parenchyma layer is covered by thick-walled collenchymatous cells (*c*); these develop more abundantly, the larger the vein is. The collenchyma extends as firm wedges somewhat above the part of the leaf surface which consists only of leaf flesh. The leaf flesh shows the usual division into palisade parenchyma (*p*) and spongy parenchyma (*sp*). Of these layers, containing chlorophyll, the palisade parenchyma does not extend over the vascular bundles on the upper side but spreads out on both sides like a keel so that it terminates in a short cell layer (*br*). This becomes one layered, between the collenchyma and the parenchyma of the body of the vein. The spongy parenchyma, on the other hand, extends on the under side over the body of the vascular bundle and forms the bark part of the vein in which, as in the bark of the branch, may be found oxalate crystals (*o*) arranged in crescent-like rows. The epidermis (*e*) covers the whole leaf uniformly.

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1 After Ritthausen; cf. "Der Landwirt" 1875, p. 501.
2 Sorauer, P. Frostblasen an Blättern. Z. f. Pflanzenkrankh. 1902, p. 44.

The mechanical action of frost is shown here in the form typical for the majority of our plants since, on the upper side of the leaf, the collenchyma tissue above the vascular bundle of the large vein is raised up from the parenchyma, thereby forming an opening (*l'*). On the under side of the leaf, the spongy parenchyma has been freed from the bark part of the vein on the scarps of the very prominent body of the vein so that cavities (h), containing air, are produced on both sides of the rib. The formation of the cavities is explained by the fact that the youthful, still hyponastic leaf, the edges of which are up-curled, from the action of frost, contracts at both sides of the mid-rib from above downward, as well as tangentially. If the up-curled, trough-like leaf contracts, the curling must become greater, i. e., the distension of the under side becomes stronger. This manifests itself in a pulling toward the raised edges (see the direction of the arrow in

Fig. 107. Cross-section through a frost boil in an apple leaf.

the illustration). The tension is the greatest at the scarp of the vein and can, at times, lead to a splitting of the epidermis (*e'*).

If thawing now takes place, the result of the action of the frost is the overlengthening of the tissue which has been strained, for the tissues are indeed distensible but not completely elastic. They do not regain their former size and arrangement. The lower epidermis, which has been most strained, elongates and no longer exercises on the spongy parenchyma, lying beneath it, the previous amount of pressure. The pressure in the epidermis is broken and the spongy parenchyma responds at once, elongating into pouches. If, at the time of the greatest tension, the epidermis is torn apart, the over-elongated edges of the tear (*e'*) form a crater-like opening toward which grow out the rows (*f*) of the spongy parenchyma which develop into threads.

We find further investigations of frost blisters in a work by Noack[1], who comes to the conclusion that they are produced "because water from the cells is pressed into the intercellular spaces and there turns to ice so soon as the temperature falls to a certain degree below the freezing point, differing for the different varieties of plants." The formation of ice crystals was found by Noack to be strongest at the place where later the separation of the epidermis becomes visible. We owe a recent study to Solereder[2]. He observed in the leaves of Buxus the same hairy outgrowth of the mesophyll cell rows that I had found in apples, cherries, apricots and have illustrated in Fig. 107. Solereder has proved experimentally that this elongation of the cells of the leaf flesh is a secondary phenomenon occurring with an abundant supply of water. He removed the under side of the leaf and set the plants in a moist place. Cuticular warts were then produced on the cell membranes, similar to those which we have illustrated by the woolly stripes in apple cores (p. 324) and have observed also in the frost blisters of cherry leaves. The beginning of this hair-like elongation of the cells is found in the sheath of the vascular bundles, i. e., in places where the cork disease of the cactus (p. 429, Fig. 71) may be recognized as the initial point of the diseased processes of elongation. We find in this an experimental proof of our theory that the disturbances named may be traced back to excess of moisture.

We will discuss later, in connection with other mechanical disturbances due to frost, the question whether the frost blisters were produced by the crystallized ice, or formed previously by a difference in tension due to the cold, thus offering for the formation of ice the most convenient places of deposit. We will for the present only emphasize the fact that the holes in the tissue pictured in the apple leaf (on the upper side of the veins and below on their scarps) are a typical frost peculiarity found frequently in very different leaves which also remain green during the winter.

Comb-like Splitting of the Leaves.

In some years with late frosts the phenomenon, in which the otherwise continuous surfaces of tree leaves often appear slit and thereby approach those forms which are characterized as *"folia laciniata"* may be found not infrequently. While, however, in commercial varieties, the slit leaf form is a condition fixed in the developmental course of the individual and may be transmitted by grafting, the slitting due to frost forms a transitory stage which, even in the same summer, may return to the normal leaf form.

I had opportunity in the spring of 1903 to observe the very frequent occurrence of the phenomenon in *Aesculus Hippocastanum*[3]. The structure shown in Fig. 108 was restricted to the lowermost leaves of the shoot, i. e.,

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[1] Noack, Fr., Über Frostblasen und ihre Entstehung. Z. f. Pflanzenkrankh. 1905, p. 29.

[2] Solereder, H., Über Frostblasen und Frostflecken an Blättern. Centralbl. f. Bakteriol. 2d Section. v. XII, 1904, No. 6-8.

[3] Sorauer, P., Kammartige Kastanienblätter, Z. f. Pflanzenkrankh. 1903, p. 214.

those appearing first from the bud. On the same leaflet could be found all transitions from deep incisions extending as far as the mid-rib (Fig. 108*e*) to the normal undivided leaf surface (Fig. 108*f*). It was observed on those transitional places that exactly in the middle line of each intercostal field and spread between two parallel, lateral veins, occurred a lighter colored, transparent stripe along which the tissue was broken in places. (Fig. 108*g*.) The edge of such a ruptured place, like the edge of the individual feathery

Fig. 108. Horse chestnut leaf, injured in the bud by frost, and torn, like the teeth of a comb, during unfolding.

tips of the slits, often shows a somewhat yellowish, harder line, sometimes appearing a little callused. This callused edge consisted of plate cork cells, to which, on the outside, were not infrequently attached rags of dead mesophyll cells. It is evident from this that the comb-like incisions had not been formed in the bud, but were produced later.

In the above mentioned, transparent lines, of which the first are broken only in places, the mesophyll is found to be dead on the uninjured part. The cell content was still abundantly present but brown and collected in

balls. The vascular bundles showed the well-known frost browning. The fact that exactly the midline of the intercostal fields is always the part injured by frost is explained by the peculiar folding of the leaf surfaces in the bud primordia.

I found the same phenomena also in *Acer Pseudoplatanus* and some other thick-leaved varieties of maple; in these, however, only in the form of irregular perforations. Laubert[1] observed a feathery slitting of the leaves of the birch and the white beech. Thomas[2] explains the slit condition of the leaves chiefly as a result of the action of the wind. It has been known, ever since A. Braun and Caspary, that chestnut leaves can be perforated and in places slit by the mutual rubbing of the leaf surfaces, but the phenomenon here described has nothing to do with the action of the wind. I have found the beginnings of the split leaf condition in little trees which had been brought into the house soon after the action of the frost[3].

The Heaving of Seeds.

Aside from the injuries which hardy herbaceous plants can suffer from lying too long under a snow cover, because they are often suffocated, we have to take into consideration another phenomenon which becomes especially disadvantageous for grains, i. e., the heaving of young plants.

It is only the soils which contain a great deal of water which exhibit the heaving of seed by frost. After unsettled winter weather, when sharp frosts suddenly follow wet days in the early spring, a number of young plants with exposed roots are not infrequently found on the upper surface of the field. A part of the roots, to be sure, still touch the earth with their tips, and eke out for the seedlings a pitiful existence, while other rootlets, perfectly free, with torn tips, are exposed to drying wind and sun. The explanation of this occurrence is very pertinent here. The heavy soil retains large quantities of water; this freezes into long, needle-like crystals and thereby raises the upper layers of the soil, together with the young seed. If a part of the fine roots have already reached a considerable depth they are torn loose. In the subsequent thawing the soil can settle back in place, but not so the young plants. A repetition of the process finally brings the above result and may cause considerable loss if help is not brought quickly. The help consists mainly in the use of a heavy roller at a time when the soil has already dried to some extent. By pressing the sprouted seed, the lower nodes of the stem obtain protection and dampness enough to put out new adventitious roots and in this way gradually overcome the injury to the organs which hold them fast and nourish them. Especially in grain plants rolling acts beneficially and in damp spring weather strong blades will grow from plants which have thus been drawn out of the soil.

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1 Laubert, R. Regelwidrige Kastenienblätter. Gartenflora, 52. Jahrg., 1903, Oktober.

2 Thomas, Fr. Die meteorologischen Ursachen der Schlitzblätterigkeit von **Aesculus Hippocastanum.** Mitt. d. Thüring. Bot. Ver. 1904, Part 19, p. 10.

3 cf. Z. f. Pflanzenkrankh. 1905, p. 234, Note.

Drainage will naturally act as a precautionary method. A loosening of moor soil by raking it over with sand may also be proved favorable. Kühn[1], in this connection, found that drill cultivation was also effective since all seeds were thus hoed in again. Between these seeds are produced thereby "small grooves into which the moisture chiefly passes and thus, under the conditions cited, an upraising of the soil is observed in the spaces between the plant rows, while the plant rows themselves remain untouched." Hedwig[2] recommends early sowing in order to obtain as abundant deep growing roots as possible and thereby to secure the plants more firmly in the soil.

Ekkert[3] recommends a surface sowing, but chiefly the growing of strong plants. In favoring this surface sowing, Ekkert seems to have been influenced by the statements of Count Pinto-Mettkau, who says that only seeds which lie deep are heaved out of the soil and, in this are torn at the base of the primary internode, i. e., at the part of the stem which is strongly elongated only in deep sowing and which raises the node of the plant toward the upper surface of the soil. This theory is shared also by Breymann[4]. Ekkert's investigations on the firmness and elasticity of this lowest part of the stem and of the roots favor the view that, in this heaving from the soil, the roots are torn sooner than the internodes. With surface sowing, it is possible that only the roots will be torn and the superficially lying grain, therefore, also carried up so that it will still remain as a possible retainer of reserve substances for the injured plant. The injury would consequently be less and more easily overcome with the additional help of a rapidly effective spring fertilizing.

Johannes rye has been recommended as a resistant variety. In wheat, a Russian variety, *Urtoba wheat,* is found to be especially resistant. However, neither variety nor depth of sowing will determine this in the end, but chiefly the constitution of the soil and its power to retain water become of especial importance.

In young tree plantations, the heaving of the seed occurs also with *black frost.* The seedlings of pines and oaks, provided with strong, long tap roots, did not suffer, but those of the superficially rooting spruce and hemlock and, among many deciduous trees, the black alder in boggy soils, do so.

INTERNAL INJURIES IN YOUNG GRAIN.

As yet, no attention has been paid to the fact that grain plants suffer internal injuries from black frosts, even if they are not heaved from the soil. These injuries, with continued wet weather, form convenient centres for the attack of parasitic fungi. Besides the common black fungi, we will

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1 Krankheiten der Kulturpflanzen 1859, p. 11.
2 cit. in Göppert, Wärmeentwicklung, etc., p. 236.
3 Ekkert, Über Keimung, Bestockung und Bewurzelung der Getreidearten, etc. Inauguraldissertation, Leipzig, 1874; cit. in Biedermann's Centralbl. 1876, p. 204.
4 Über das Auswintern des Weizens, des Rapses und des Rotklees. Biedermann's Centralbl. f. Agrikulturchemie 1881, p. 829.

also find the snow mold, the breaker of the rye blade, the killer of the wheat blade, etc., all of which cause the further destruction of the plant. Besides the browning of the vascular bundles in the plant nodes, the frost injuries, predisposing the plant to fungous diseases, consist especially of a blister-like raising of the outer membrane in definite places of the grain leaf. Such blisters are found even in very young leaves in the bud as is shown in the adjoining Fig. 109. We find that the outermost edge (*B*) of the young leaf is so injured by frost that the cell contents have become brown and rounded, the cells have collapsed and, therefore, die in a short time (*gs*). On the

Fig. 109. Young rye leaf, injured by frost, with eruptions on the epidermis.

other hand, the part of the leaf spirally rolled up (*A*) appears perfectly fresh and capable of further development.

The leaf, of which the outer side, while in the bud, is curved outward like a bow, possesses a main vascular bundle (*g*) above which are deposited hard bast cords (*b*) on the outside, and also weaker bundles (*g'*), ramifying in the middle, broader region of the leaf, which nourish the increased mesophyll. Among the changes in tissue produced by frost, the one should be emphasized in which the enlarged cells (*r*) become noticeable after the thawing. These are radially elongated and in part irregularly pulled out of shape (*z*), with greatly bowed walls. This condition proves the presence

of abnormal tension conditions. To these should be ascribed also the very conspicuous phenomenon of the production of holes (l) regularly arranged. The holes are produced by the blister-like upraising of the epidermis from the real leaf flesh, usually on the upper side, between the rows of stomata (sp). The under, or outer side, of the leaf shows only scattered holes of small extent. The tangential elongation of some of the epidermal cells, noticeable at times (ep and ez) offers an important proof of the production of these holes. The epidermal arch has become larger than it was before the action of the frost; this elongation is the result of the stretching of single cells. Besides this upraising of the leaf, a radial splitting in the vascular bundle indicated at l' is very characteristic of frost injury; this becomes of especial importance in the axillary body.

To distinguish the formation of holes, due to the action of frost, from the tearing of the tissue, due to senility, we give in Fig. 110 the cross-section of the first sheath-like leaf of a rye plant, the inner tissue of which, in the

Fig. 110. Natural cavities in the sheath-like rye leaf, formed during growth.

course of normal development, splits at death. The holes (h), produced thereby, are *always tangential.*

Internal Injuries in the Grain Stalk.

More important, however, than the leaf injuries is the effect of frost in the stalk itself. We usually have no suspicion of this, since, to the naked eye, no change is noticeable in the plant. Fig. 111 illustrates a lower node of rye injured by frost.

The tissue of the stalk (H) is firmly enclosed by the sheath (Sch), the outer epidermis of which is indicated by e, the inner by e' while e'' indicates the upper epidermal cells of the stalk. The browning of the ducts in the different bundles, which occurs in all frost injuries, is indicated at u and u' where the narrower spiral ducts between the wide annular ducts seem the most injured. At br are found aggregations of brown parenchyma cells in the sheath; at br' the same in the stalk itself. At v and v' are shown brown groups of cells in the sheath and in the stalk, the walls of which are very strongly *swollen up* so that the whole cell seems converted into a uni-

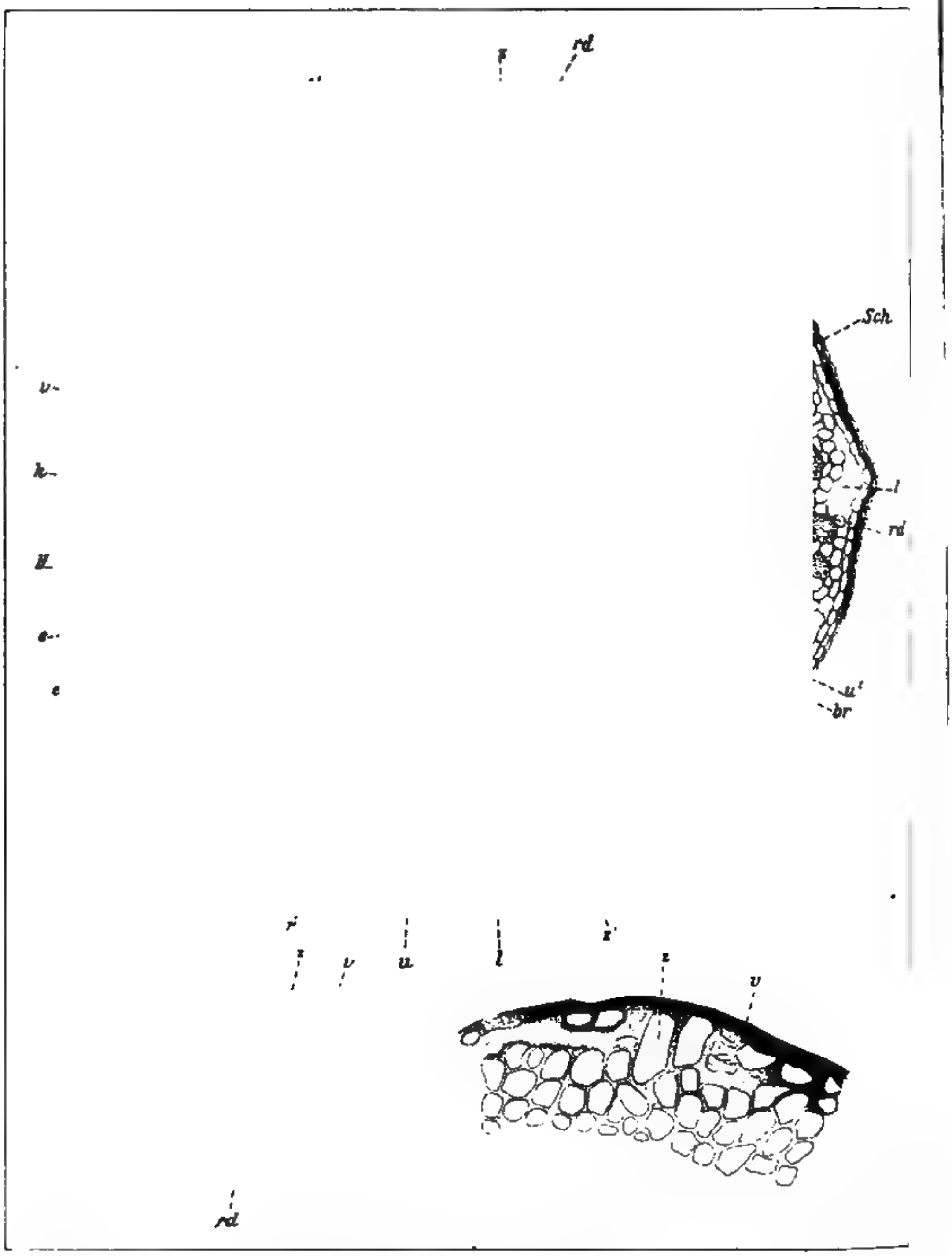

Fig. 111. (Upper figure) Leaf node from a rye plant, injured by frost.
Fig. 112 and 113. (Lower figures) Swelling of the membranes on the leaf sheaths of a rye blade injured by frost.

form yellow, gum-like mass. At other places (*r*) the parenchyma in the inner part of the sheath is torn or is filled with peripheral holes, due to the raising of the epidermis. Elongated cells occur near such holes or often instead of them, and point to the fact that, in freezing, the stalk is most often contracted tangentially, thus pulling the epidermis out of shape. Because the epidermis is not so elastic as the rest of the bark tissue, it remains permanently elongated as the result of this tension. When the frost ceases, it is raised in places (*l* and *l'*), or perforated, and its pressure on the underlying parenchyma decreases, causing the parenchyma cells to elongate into pouches (*rd*). The elongated cells, usually under the outer epidermis (*z*), but more rarely on the inner side (*z'*), often possess strongly curved, or stretched walls.

These conditions are magnified and illustrated in Figs. 112 and 113. Here the processes of wall swelling appear to be so great that one is able to distinguish only indistinctly the limits of the individual cells; some cell lumina disappear almost entirely (*v*). The loosening of the epidermal pressure, connected in the above case with the phenomena of swelling, has caused the over-elongation of the underlying tissue and the formation of considerable groups of bent, abnormally enlarged cells in some places (*rd*) and isolated ones (*z*) in others.

Finally, the phenomenon of splitting within and around the vascular bundles is most worthy of consideration. In the vascular bundles the splitting takes place usually in a radial direction (Fig. 111*k*); in fact in such a way that the more tender tissue between the two wide ducts is torn. The part surrounding the vascular bundles can be so greatly torn (*r*) that the bundle projects into the cavity. This phenomenon gives the impression that the parenchyma had contracted so strongly, as a result of the frost action, that it is torn off from the resisting, firm bundles. In case such differences of tension make themselves felt less extremely, the parenchyma near the bundles is only greatly strained, causing a subsequent production of enlarged cells with curved walls (*z'*).

Injuries to the vascular bundles, for which the vascular elements must certainly compensate by their conductive activity, are of great importance to the life of the plant. This explains the developmental retarding of plants injured by frost. Such plants, even without the cooperation of the parasitic organisms, which especially seek out weak seed, furnish less straw and especially badly nourished grain. As a rule, however, there is an additional parasitic injury due to rust, black fungi and other leaf and beard inhabitants. The development of the stalk is irregular since all plants in the field never suffer equally strongly; besides the individual differences in power of resistance, the inequality of the soil sometimes favors the frosts and sometimes gives protection from them. The more injured specimens stand under the shade and pressure of vigorously growing ones. A deficiency of light and air and the increase of moisture among the oppressed plants favor the infection and extensive distribution of the fungi.

Lodging of the Stalk.

The frost injuries above described in stalks show different secondary phenomena, according to the place where the frost acted most intensively. The most common case is where, with late frost, the base of the stalk is attacked. Usually these injuries occur in definite centres in the fields because the cold air accumulates in low-lying hollows. Here also most of the moisture from atmospheric precipitations collects so that parasitic infection is added to the frost disturbances. The base of the stalk begins to molder and the stalk itself falls over. Many of the cases of lodging of the stalks, ascribed to Leptosphaeria and Ophiobolus, are found to be combination phenomena of which frost is the primary cause.

There are, however, other cases, in which the stalks do not break at the base but at different heights. The phenomenon does not always occur in definite centres in the field but may also be found in bands and manifesting itself in such a way that healthy and diseased stalks stand side by side. Such cases not infrequently cause disputes since they bear a great resemblance to *injuries due to hail.* Reparation is refused by the Hail Insurance Companies since it is not possible to prove where the hailstones have hit.

In the basal lodging of the stalk, its ground tissue is found to be brown and the shoot almost entirely dead. It is often, indeed, soft and always infested by fungi; also bacteria, mites and anguilla in continued dampness. When the break occurs higher in the stalk, the ground tissue seems firm and green and the shoots die only in places, often without infection by fungi. Most frequently the broken place in the stalk is found at the second or third internode above the surface of the soil and is characterized sometimes as a one-sided, sometimes as a circular brown zone, the coloration of which increases in intensity towards the next higher node. Accordingly the part of a stalk, lying close below a node seems to be the most susceptible place. Nevertheless, the node adjoining the upper side of the deep brown tissue can frequently lead to a secondary upbending of the fallen stalk so that it finally stands upright again beyond the bent place. But the heads of such plants are weak and imperfect; the roots appear healthy, the brown part almost always without any fungous growth.

The Condition of Sterile Heads.

A disease which apparently has the least connection with frost injuries is the *condition of sterile heads,* as met with in Fig. 114, *A* and *B*. As yet I have found the phenomenon only in rye and will describe only a special case which I had opportunity to observe in June, 1900[1]. Here the stalks were mostly of a normal size and vigorous growth, but the uppermost member, or the one next below it, had pale yellow spots. Later these became straw-colored to a brownish-yellow, often with darker edges, which en-

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[1] Sorauer, P. Über Frostbeschädungen am Getreide und damit in Verbindung stehende Pilzkrankheiten. Landw. Jahrbücher 1903, p. 1.

Fig. 114. Different forms of sterility.

larged to a band girdling the stalk. In other cases the stalk was perfectly healthy up to its uppermost internodes.

The uppermost leaf sheaths and leaves, however, had straw-colored specks (Fig. 114 *B t*) or pits. The upper part, together with the base of the spindle of the head, was a reddish straw color. The spindle itself was brownish, dotted with salmon spots, entirely bare at the base (*k*) but, further up, covered with papery glumes, at first thread-like but later becoming somewhat broader (*sp*). The tip of the head could develop fully, as shown in Fig. 114, *B*, and the nearer this green tip the thread-like, white glumes stand, the coarser and larger they become and the more their constitution approaches the normal condition. At times groups are found with green fleshy glumes on the part of the spindle which remains bare (Fig. 114, *B g*).

Fig. 114 *A* reproduces a case in which the lower glumes are normal and green. The upper ones are normal in size and form but have a reddish, straw-colored appearance; the

spindle is naked between the tip and the base. In more extreme cases of injury, in place of the head, only a bare, brown membraned spindle with salmon-colored spots remains. The salmon-colored points are the places of attachment of the grains and colored by luxuriantly developed tufts of fungi.

In almost all cases of sterile-head condition, the axis is bent in the form of a crook (Fig. 114 *B g*) by the drying of the bare part of the spindle. In the examples pictured, it is clearly seen that the sterile head condition owes its production to locally effective causes. When these phenomena were studied on a field where especially many plants had suffered from sterile-head condition, it was noticed that the zone of injury could be found at approximately equal distances from the soil. Therefore, the injurious cause must be found in a layer of air which is present exclusively at a certain distance above the soil. The rye plants, affected in different stages

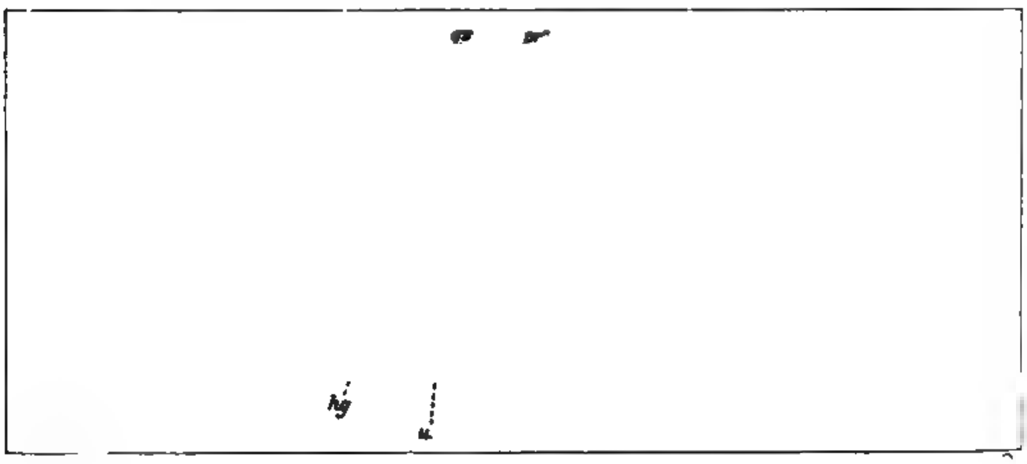

Fig. 115. Cross-section through the internode of the head of a rye blade suffering from sterility.

of individual development, are injured differently, according to the extent to which they have penetrated into this injurious air layer.

It is thus evident that sometimes the lower part of the head will become bare, sometimes the upper part. In the best developed, tallest plants, in which the heads, standing on the longest stalks, are already above the injurious air layer, the heads remain perfectly uninjured; only the uppermost section of the stalk has a pale band.

In discussing the cause of this sterile-head condition, the supposition would seem most pertinent, that the disease is caused by the fungus, recognizable on the band and especially on the spindle of the head and appearing in salmon-colored ridges at the places of attachment of the blossoms.

This hypothesis, however, is erroneous since even greater injuries to the spindle have been observed when the presence of the fungus could not be proved. On this account, this fungus, which belongs to the genus Acre-

monium, is to be considered as a secondary infection, just like the almost omnipresent Cladosporium.

If now the injured spindle is examined in those places which Acremonium has not infested, the pictures reproduced in Figs. 115 and 116 are obtained. Fig. 115 represents a cross-section through an internode; Fig. 116, one through a node of the head spindle; *e* indicates the epidermis; *h*, its hairs; *g*, a healthy vascular bundle; *g'*, a bundle with shrivelled brown walls; *gs*, vascular bundle sheath; *b*, bast parenchyma; *hg*, wood part of the bundle; *u*, deep brown tissue between the two large ducts, which is very sensitive and is proved to be injured first by various causes; *pr*, healthy prosenchyma cells; *pr'*, the same with healthy walls but brown, filled lumina;

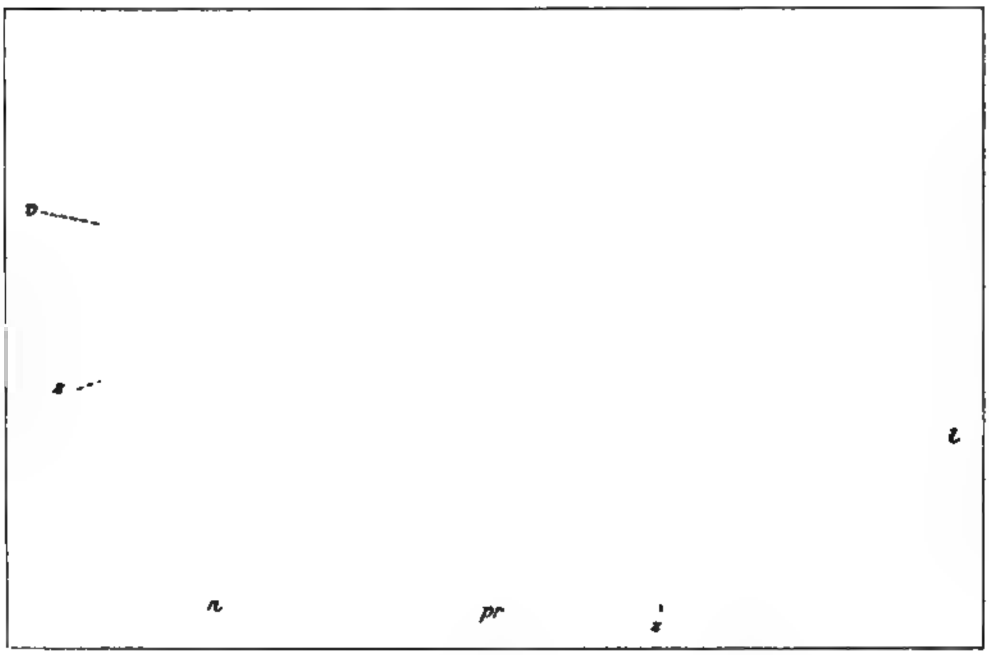

Fig. 116. Cross-section through the node of the sterile stalk.

pr", prosenchyma possessing colorless cell cavities but deeply browned walls; *v*, parenchyma cells in the epidermis and bark tissue with yellow, thickly swollen walls and barely distinguishable lumina; *z*, elongated cells near the gum-like, swollen tissue centres; *bl*, basal part of a head which separates here from the node.

Thus, in the bare parts of the head spindle, all those forms of injury are found, which are noticeable in the lower nodes of all frost-injured grains, only, instead of clefts in the tissue, swellings of the membrane predominate. These are especially extensive at the places of attachment of the heads because much more abundant parenchyma tissue, i. e., tissue more susceptible to frost, is present there. And such *gum-like, swollen tissue centres lie deep in the interstices of the spindle.* By means of this ana-

tomical condition, the sterile heads, due to frost, are differentiated from the similar, well-known injuries to the heads due to thrips, the suction-points of which remain superficial. At any rate, thrips are found not infrequently on heads injured by frost since these animals seek out weakened organs; but their usual small number and the change in the tissue of the spindle leaves no doubt that the infection is secondary.

The fact that I have succeeded in producing, *by artificial frost, all the injuries to leaf, stalk and head described here* is decisive. All the different forms of shrivelling of the grain could also be produced experimentally.

The condition of sterile heads due to frost occurs only in different years and not extensively except in definite localities.

The thought that only certain parts of the stalk are injured by frost, as must be presupposed in the condition of sterile heads, at first seems strange, but one at once becomes more familiar with it if the affected regions are examined. Either the basal part of the head, which appeared last from the sheath, together with the adjoining upper part of stalk, is affected, or the part of the internode lying directly under the node, showing the frost band. The parts named, however, are the most tender and susceptible of the whole stalk and we find analogous phenomena also in dicotyledonous plants where the stems of the blossoms and fruit are injured and blackened only directly at the base of the blossom, while the older part remains healthy.

It could not be determined by observation what atmospheric conditions must exist in order to produce interrupted heads or bands on the stalks, because attention was not called to the phenomenon until some time after the action of the frost. Some of the meteorologists consulted incline to the opinion that dew plays a part in this.

Frosty nights in May are usually windless and the injury to the plants results from the cooling down of the organs by their radiation of heat. The upper surface of the soil itself cannot be cooled down very greatly in a close standing rye field since it retains its daily warmth for some time through the mantle formed by the air, found between the stalks, which can be moved with difficulty. The greatest amount of cooling through radiation can take place only in the upper part of the stalks. These, however, are covered by the evening dew. The morning wind rises suddenly with the sunrise and starts a rapid evaporation of the dew. The cold, due to this evaporation, can fall even below the freezing point. The places with a lesser amount of dew, the parts which are protected by other stalks lying in front of them, thus remain protected from this cooling down to the freezing point. The distribution of the dew on the same part of the plant, however, will differ since the places which, through bending, are inclined more horizontally than others, will retain even larger amounts of dew. Among the organs exposed to the freezing temperature, however, only especially tender ones will suffer. This explains the fact that on a head isolated places alone can be injured. In addition to the fact that the base of the head is proved to be the most injured, the circumstance that the

frost does not injure the organs richest in cytoplasm first but, under similar conditions, those poorest in it is a further explanation.

The grains at the base of the head are, however, the most poorly nourished and poorest in cytoplasm, as may be recognized in any healthy head of grain.

As a result of a conversation with the director of the German Naval Observatory, Admiral Herz, the latter sent me later, most kindly, the following explanation: "In a stand of plants, whether high or low, the soil is, on the one hand, protected against the nocturnal radiation, while, on the other hand, this radiation takes place strongly from the surface of the plantation and, because of poor warmth conductivity, is very effective. However, the air, cooled near the leaves, sifts down through the plantation just as on declivities it sinks into depressions in the soil. It is, therefore, very conceivable that the lowest air temperatures begin somewhat below the upper surface of such a plantation, especially if its denseness increases towards the ground, or if the tips are protected from too extensive cooling by a light wind."

The way in which the processes actually take place out of doors which bring about the injurious cooling of different horizontal air layers at considerable distances from the upper surface of the soil is left for further observation. The experiment, in which a wooden cylinder, with a mantel containing a cold mixture was set over the upper part of the blossoming rye stalk, proves that the condition of sterile heads is produced by such action of the frost. Because of the impossibility of rapidly mixing the individual horizontal air layers in the freezing cylinder it was proved that only a definite zone was so cooled down that it brought about the described injury to the heads.

We conclude, for example, from Nördlinger's observation[1] that the injuries take place in forest trees and indicate the existence of a layer of air, which causes death from frost above the warm surface of the soil. Nördlinger found in June, 1862, in the Hohenheimer Oberen forest young shoots of willow, oak and aspen frozen at the base of the petioles, and in August, 1883, several kinds of willow, especially *Salix fragilis,* when there had been no night frost.

Phenomena of Movement Due to Frost.

In many plants surviving frost peculiar ***phenomena of movement*** result from freezing, which disappear again with thawing. Göppert[2] mentions Linneus' observation that the leaves of the milkweed (*Euphorbia Lathyris*) bend their tips backward until the leaf lies against the petiole. The leaves of the wall-flower (*Cheranthus Cheiri*) look wilted in the frozen condition and often bent, but after thawing they regain their former consistency and position.

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1 Nördlinger, H., Lehrbuch des Forstschutzes. Berlin, P. Parey 1884, p. 347.
2 Warmeentwicklung in den Pflanzen, p. 12.

Wittrock[1] perceived in the phenomena of movement a protection against the cold of winter. For example, the evergreen root-leaves of numerous plants bend backward and downward so that at last the outermost part of the under leaf surface seems pressed against the soil; in summer they have a slanting position. This is especially clearly noticeable in *Hypochoeris maculata* L., *Geum urbanum* L., *Cerefolium sativum* L., and others. Also a few early spring plants like *Ranunculus Ficaria* L. behave similarly. Hartig recognized in these phenomena rather a *wilting of the parts of the plant,* resulting from the limpness of the cells, from which the water has been frozen out into the intercellular spaces. Since the freezing of the water in the various parts of the organ will differ according to the age and maturity of the tissue, the difference in the movement, due to frost, might be explained in this way.

Such phenomena of movement, however, seem in no way connected with the formation of ice and are only extreme cases of thermonastic reaction which, as Pfeffer[2] states, are expressed in the nocturnal drooping of the blossoms, leaves and shoots. Vöchting[3] observed in *Mimulus Tilingii* Rgl. that shoots of a certain age grow upward in the spring with a high temperature or maintain a horizontal direction with a low one, while in case they have developed an upright position, they reassume the horizontal one. Light and humidity have no influence. He believes that with continued low temperatures the plant might develop only creeping shoots on which blossoms are never produced. This sensitiveness ceases in the blossoms which are termed *psycho-clinic.* Lidforss[4] concludes from numerous observations on Holosteum, Lamium, Veronica, etc., with which klinostatic experiments were also made, that in such movements not only changes in turgor are concerned but actually the effects of stimulation. With a higher temperature the petioles are negatively geotropic, but in temperatures below 6 degrees, they are dia-geotropic and epinastic. Here, however, the light acts as a modifier since, with its exclusion, the petioles, in spite of the lower temperature, are no longer dia-geotropic but negatively geotropic.

The movements of the peduncles of *Anemone nemorosa* are, on the other hand, of a purely thermonastic nature. They curl downward with a lower temperature but stand upright with a higher one.

In petioles and leaf surfaces, the resumption of a horizontal position is often noticed, or a bending backward below the horizontal plane on taller, upright axes. In this, however, we wish to emphasize the fact that the movements take place usually in the points and are not always of the same nature in the same plant. It can happen that, in compound leaves, some of the leaflets turn upward while the majority bend downward; that, therefore,

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1 Bot. Ges. zu Stockholm. Sitz. v. 24. Oktob. 1883; cit. Bot. Centralbl. 1883, No. 50, p. 350.
2 Pfeffer. Pflanzenphysiologie, 2d edition, v. II (1904), p. 495.
3 Bot. Jahresb. 1898, I, p. 582.
4 Lidforss, Bengt. Über den Geotropismus einiger Frühjahrspflanzen. Jahrb. f. wiss. Bot., v. 38, 1902, p. 343. (Z. f. Pflanzenkrankh. 1903, p. 277.)

sometimes the morphologic upper side, sometimes the under side of the joint cushion is shortened. Among the changes appearing especially clearly with ice formation, the curling of the leaf surfaces should be emphasized. An example very easily observed is furnished by our Rhododendron. Harshberger[1] describes a case of *Rhododendron maximum* in which the petioles sank to 70 degrees while the edges of the leaf curled backward so much that the upper surface appeared convex. If the plants were brought into a warm room, their leaves resumed their normal position after 5 minutes. Hartig ascribes this process to a peculiar irritability of the cytoplasm while I assume differences of tension between the differently constructed layers of tissue.

In many woody plants a movement of the branches and twigs proportionate to the degree of cold is found. According to Caspary[2] *Acer negundo* and *Pterocarya caucasica* direct their branches upward, while Larix, *Pinus Strobus* and *Tilia parvifolia* lower their branches. *Aesculus Hippocastanum* and *Aesculus Hippocastanum rubra,* as well as *Carpinus Betulus* lower their branches with a slight degree of frost and raise them again when the cold becomes greater. Simultaneous with this raising and lowering is a lateral motion, in some varieties toward the right, in others toward the left. In *Cornus sanguinea* Frank[3] found that the one to three year old branchlets became wavy and twisted above each other. Most of the twistings were found to be clearly directed toward one and the same point of the compass so that Frank concluded it was the effect of a current of cold air coming from a certain direction.

As stated above, we might seek the causes for the movements in leaves and petioles, as well as in branches, in differences of tension which takes place, partly because of changes in turgidity, partly from unequal contraction of different tissue forms within the same organs due to the appearance of cold.

An experiment which I carried out with *Aesculus Hippocastanum* proves that an increase of turgidity of the parenchymatous tissues in *"leaf wilting due to frost"* can, under certain circumstances, again cause the stiffening of those leaves.

A three year old potted specimen was put into a warm place in February. It developed very vigorously until the middle of Márch so that the terminal shoot, 14 cm. long, had developed six leaves. The largest leaflet of the two youngest leaves was 2.5 cm. long and in the lower, older leaves the length of the petiole was from 5 to 9 cm.

The plant was put out of doors on March 14th. The following night the temperature fell to 2.5 degrees C. below zero, and the next morning a sharp bending or breaking of the petioles was noticed on four of the older

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1 Harshberger, John, Thermotrophic movements of the leaves of **Rhododendron maximum**; cit. Bot. Jahresb. 1899, II, p. 141.
2 Report of the International Horticultural Exhibition, etc., London 1866; cit. in Nördlinger, Forstbotanik, I, p. 201.
3 Frank, A. B., Krankheiten d. Pflanzen. Breslau 1895, v. 1, p. 187.

leaves, approximately in the centre or somewhat below it. The places of breaking were flatly compressed and began at once to become flabby. The tips of the leaflets, which otherwise did not appear wilted, were flabby on the broken leaves and began to turn brown.

Since such a breaking of the petioles had not been observed previously, this plant was again placed out of doors on the night of the 21-22d of March. The temperature fell to 7 degrees C. below zero and the next morning the leaflets of all the leaves hung downward at a sharp angle. The *youngest* leaves showed this phenomenon the least of all. Even in a still frozen condition, no part of the young growth seemed brittle, or of a glassy consistency, so that any conclusion as to a formation of ice crusts in the tissue was scarcely possible. The leaflets were soft and flabby, of a grayish green color, and the petioles, as long as the plant stood out of doors, curved downward sharply but were not broken. The breaking took place only after some hours indoors and, indeed, as in the first observed injury, near the middle of the petiole. This place shrivelled at once and turned brown. At the same time all the leaflets, with the exception of the youngest, began to turn black, starting at their place of insertion, and the tips curled upward and became dry.

The processes of breaking must be traced back to a lever action connected with decreased turgidity, for, as soon as some of the leaves, broken by weak frost action, were removed and placed in water, they lost the appearance of wilting in spite of the broken place, and a great stiffness of the tissues set in. To be sure, the leaflets retained their downward inclination, peculiar to the youthful stage, but their intercostal fields curved outward strongly between the veins and their side edges began to turn under.

The wilting and breaking is explained by the inner phenomenon of cleavage in the pith body of the petioles. In the chestnut the petiole has a structure similar to the trunk, inasmuch as it possesses a closed circle of vascular bundles which completely and uniformly surrounds the broad, colorless pith disc and passes over into it in a gradation similar to the pith crown. Even after the weakest frost action it was noticed that the pith body of the petioles which had not yet broken, contained holes, usually of a radial arrangement, and seemed ready to break, because of the limpness of the corresponding place. This occurred near the base of the petiole. Because the vascular body, running through the centre of the pith disc and consisting of two or three bundles, remained intact and the tears in the pith parenchyma ran radially to all sides, a peculiar star-like figure of cleavage was sometimes found. In the leaves, which had been broken only after a second, stronger frost action, the splitting of the pith disc at times was so strong that the central vascular bundle cord was connected with the peripheral vascular bundles only by a slender parenchyma strip and all the rest of the pith disc had been dissolved. The holes were continued, not infrequently, in or between the peripheral vascular bundles and formed splits which extended to the edge. Within these occurred also tangential out-

pushings of two to four outer collenchyma layers, with a tender, inner tissue. The latter tissue was seen to be rich in chlorophyll and at times, in fact, showed still definite chlorophyll grains. Similar disturbances could be proved also in the midribs of leaves more greatly injured.

Here the phenomena of browning were first perceived in the walls of the ducts and then in the various peripheral groups of the bark.

In wilting out of doors, due to frost, naturally such an increased supply of water, as obtained here in the experiment by placing the cut leaves in water, cannot take place and, on this account, the wilted organs retained for some time, or permanently, the wilted condition, especially if a splitting of the tissue and changes in the ducts reduced the conductivity. This can take place differently not only in the different varieties and individuals, but even in the different branches of the same specimen. An example of this was furnished by an elm which stood in a pot and in winter was brought into the hothouse for forcing. The little tree, which had been exposed to a frosty night at only 1 degree C. below zero, had developed two forked apical branches which approximately corresponded to one another in length, leaf number and size. In this frosty night, however, only scattered leaves of one shoot had begun to wilt but did not change color. The relaxed organs did not recover after several days retention in the warm room but showed no advance of the wilting. It is clear from this that *wilting due to frost* is a very local phenomenon not directly connected with the upward forcing of water by the root.

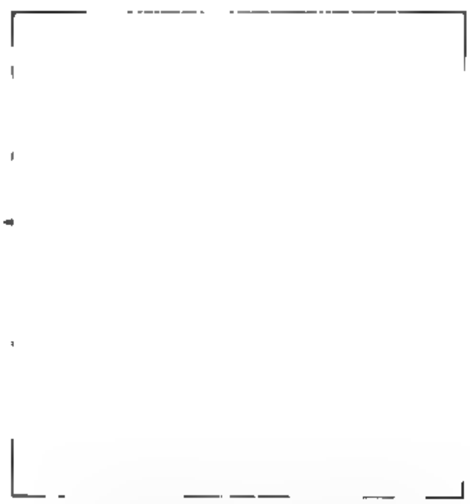

Fig. 117. Cross-section through a spruce branch. In the inner part of the wood disc the solid red wood is shown on the upper side of the branch but in the outer annual rings it is seen on the under side. (After R. Hartig.)

In the phenomenon of the movement of twigs the different kinds of movement may be easily explained if the structure of the individual branches is more closely observed and it is seen how, in the maturing of the annual rings, the thin-walled spring wood (Fig. 118) constantly changes to a thick-walled autumn wood with small lumina. In this connection the studies of R. Hartig[1] should be compared showing the change from thick-walled, red wood to the light, porous strain wood within the same cross-section of a spruce branch. In the adjoining Fig. 117 the red wood is found especially strongly developed in the first annual periods on the upper side of the branch. In later years these showed a sudden change, since rather the

[1] Hartig, R., Holzuntersuchungen. Berlin, Springer, 1901, p. 50.

Fig. 118. Red wood from the under side of a spruce branch (Cross-section). The uppermost cell row is spring wood; the lower four rows are red wood with large intercellular spaces (at the left). (After R. Hartig.)

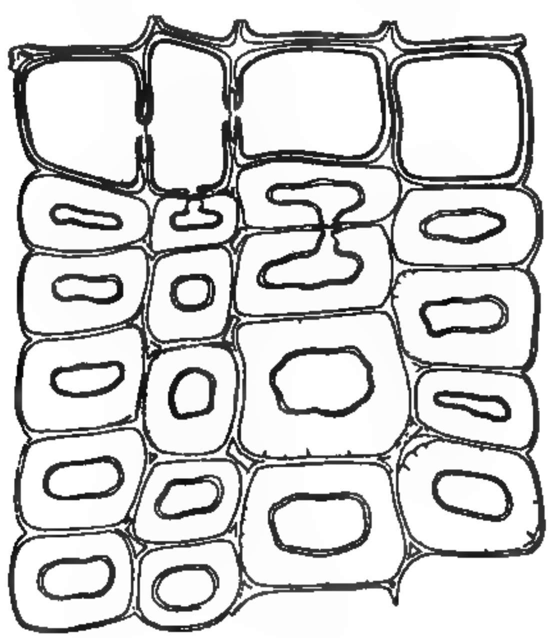

Fig. 119. Cross-section through strain wood on the [illegible]face of a spruce branch. (After R. Har[illegible]

under side of the branch appears dark because of the dense formation of red wood. We perceive in the anatomical pictures in Figs. 118 and 119 the different structure of the elements of the *"red wood"* and *"strain wood."*

We obtain from R. Hartig reports, well worth considering, as to the production of such differences. He states that, for example, in trunks with an eccentric growth, the formation of the annual rings is especially strongly developed on the branched side. The formation of red wood is proved to be often dependent upon the prevalent direction of the wind, since the side away from the wind favors red wood formation. If the west wind, for example, strikes a spruce constantly, the west side will be strained. The east side, toward which the tree is bent, is more strongly pressed and incited to a stronger formation of red wood while the windy side, stretched by the bending of the trunk, produces strain wood. Every branch will show just such differences, for the weight of the needles will bend it downward. Its morphologically upper side, therefore, is under a constant strain which exercises a stimulus on the cambium. This consequently forms thinner-walled, less woody but longer tracheids and these represent the "strain wood."

Besides the action of the wind, the formation of the wood on every branch is influenced by its surroundings. Shade from other trees, or proximity to cliffs or walls, the one-sided effect of greater moisture, partial defoliation due to the grazing of animals, or other *one-sided changes in the nutrition of the branch* will call forth a lack of uniformity in the quantity and quality of the annual ring. From this it is clear that, in the action of cold, the contraction of the tissue must vary greatly and the depression of the branches must be very manifold, according to the distribution of strain and red wood. Therefore, the observations made by different investigators can have no general significance but should only be registered for the present as individual cases.

We will discuss thoroughly the differences due to strain in the section on "Internal Cleavage."

Freezing Back of Older Branch Tips.

A freezing back of the branch tips is found in some of our woody plants, almost as regularly as defoliation. Mulberry trees, acacias and raspberries furnish the commonest examples of this. We owe more exact studies on this point to v. Mohl[1], who refers to the different stages in which our woody plants are found at the beginning of the winter.

In many plants the growth of the branches continues undisturbed so long as the conditions are at all favorable for further development. This growth only stands still during the period of cold and, as soon as the temperature allows, begins again immediately at the point where it stopped in the autumn. This is the case in the ivy (*Hedera Helix*) and the Savin

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[1] Bot. Zeitung 1848, p. 6.

(*Juniperus Sabina*). In many trees the developmental period of a branch ends of itself towards the close of summer. In this a terminal bud is formed which, the following spring, takes over the direct continuation of the branch, as in fruit trees, oaks, ashes, spruces and firs. In our cultivated plants the case often occurs when a second shoot (*Johannestrieb*) is developed in the same year. This not infrequently produces unripe wood which freezes easily in winter, while the wood of the *spring shoot* is always completely matured. A third large group drops the tip of the branch all at once in the course of the summer while unfolding, where the development is otherwise perfectly normal. The continuation of the branch is then taken over in the following year by the uppermost, lateral bud as shown in *Gymnocladus canadensis* and *Ailanthus glandulosa*. Further examples are offered by the linden, the elm, the plane and the hazelnut. v. Mohl proved that the trees, the tips of whose twigs almost regularly freeze, belong to this last group. Specimens, for example, in Rome have regularly thrown off the tips of their branches in October and thus have actually closed their period of growth. This happens in the case of the linden. In trees of this group, which are favorites in planting, such a normal ending of growth does not take place in the majority of cases. This indicates that our summer is too short and too cold for them to reach full development.

Frost, therefore, always attacks immature growth. Here belong *Robina Pseudacacia*, Gleditschia, *Sophora japonica, Broussonetia papyrifera, Morus alba, Salix babylonica* and *Vitis vinifera.* If the twigs are to be retained, their premature defoliation would be advisable. Thus, for example, according to the observations of Lawrence[1] in the winter of 1708-1709, of all fruit trees, only the mulberry survived because its leaves had been picked for feeding the silk worms some time before the occurrence of the cold.

In our fruit trees, the dying of the branch tips, as a result of the occurrence of winter cold, is usually termed tip blight. Not infrequently, however, a resulting phenomenon is associated with it, which first makes itself felt in summer. If it happens in many branches that only the especially delicate basal rings are injured, these branches, as a rule, develop further and the blossom buds already formed develop fully. About June, however, a *yellowing of the foliage* appears, a dropping of the fruit already set and a drying of the twigs. As a result of the injury to the branch ring, the conducting of the nutritive substances is disturbed and the branches themselves remain alive only as long as reserve substances are present. After these are used up the branch dies.

In grapevines the case in which the vines freeze back to the old wood deserves especial mention. There then develop from the base of the trunk uncommonly luxuriant shoots which, it was formerly thought, would be

[1] Göppert, Wärmeentwicklung, p. 5.

sterile in the next year and only bear fruiting wood the year after. Opposed to this theory, the investigations of Müller-Thurgau[1] have shown that such wood, even in August of the year of its production, can form fruit buds and that the treatment of the vine is to be planned accordingly.

The Dying of the Cherry Trees Along the Rhine.

As a special example of the phenomenon previously described, we will consider the disease of the sweet cherry in the provinces of St. Goar, St. Goarshausen and Unterlahn which has been much discussed since the beginning of this century.

According to the material[2] which I obtained from that region, and cases which I observed elsewhere, the phenomenon appears as follows: a turning yellow of the foliage of some branches, or of the whole crown sets in rather suddenly and usually with the appearance of considerable gum exudation; the branches, or even the whole trunk, die. Often the tips of the branches develop further while the rest remains bare. Microscopic investigations determine a high degree of gummosis; gum holes can be found even in the youngest shoots. In the wood and in the bark body, the phenomena of browning are often found, which we will discuss later when describing the action of artificial frost. Indeed these are provable often in the apparently healthy shoots, leaves and fruit stems. In older trees definite forms of tissue clefting are frequently found which correspond with those produced by artificial frosts. Because of this discovery, I am of the opinion that not only in the "Dying of the Rhenish cherry tree," but also in similar cases which appear often but usually to a lesser extent, frost action at the time of the spring growth is to be considered as the actual cause.

Göthe[3], who agrees with our theory, describes as follows the weather conditions for the localities lying along the Rhine, in the year when the disease appeared: "The cherries were already in bloom when on the 22nd of March they were surprised by a drop in temperature to 9.7 degrees C. below zero. In the course of the spring abnormally strong fluctuations took place between great cold and great warmth. I consider such weather contrasts to be the cause of the very numerous cases of subsequent disease which, in the stone fruits, are almost always connected with strong gummosis and are accompanied by infection with wound parasites or parasites of weakness. Also, for the special case on the Rhine, such a fungus *Valsa leucostoma* was at first made responsible[4]. Soon after, however, Wehmer[5]

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1 Müller-Thurgau, Über die Fruchtbarkeit der aus den älteren Teilen der Weinstöcke hervorgehenden Triebe, sowie der sog. Nebentriebe. Der Weinbau 1882. No. 28.

2 Sorauer, P., Das Kirschbaumsterben am Rhein. D. Landwirtsch. Presse 1900, p. 201.

3 Göthe, R., Das Absterben der Kirschenbäume in den Kreisen St. Goar, St. Goarshausen u. Unterlahn. D. Landwirtsch. Presse 1899, p. 1111.

4 Frank, A. B., in D. Landwirtsch. Presse 1899, No. 83, p. 949.

5 Wehmer, Zum Kirschbaumsterben am Rhein. D. Landwirtsch. Presse 1899, No. 96.

drew attention to the fact that this fungus, which Frank at first had described as *Cytospora rubescens,* was not able to produce the disease but should be considered as a secondary phenomenon, just like the simultaneous occurrence of bacteria. Aderholt[1] first cited the experimental proof that Valsa is not able to penetrate at once into *healthy tissue.* This investigator found, in his artificial freezing experiments, that the co-operation of late frosts was unmistakable in the growth of fungus.

In regard to the above named fungus, Aderholt is of the opinion that if the fungus requires, for its infection, the injury produced by frost or some other good cause, it still is able to strengthen itself later so much that it can spread parasitically. This theory agrees perfectly with that of Vuillemin[2] in regard to the cherry disease observed in Lorraine in 1887, which bears great similarity to the one here discussed; *Coryneum Beijerinckii* is named as the cause, and the author associates with it *Ascospora Beijerinckii* as the ascospore stage. It would thus seem to be the theory of the above investigator that climatic causes have produced the condition for the disease but the fungus produced the disease itself. Accordingly, in combatting this disease, all wood infested with Valsa or its conidial form, the Cytospora, must be carefully destroyed.

However, we obtain an insight into the real relation of this fungus to the disease only from the very recent inoculation experiments which Lüstner[3] has carried out. Among others, he took two small cherry trees of different varieties and broke back their crowns. The end broken and the piece of the trunk left standing were inoculated with the conidia of the fungus and also later painted with water containing them. Since the crown did not die back as a result of the breaking, it was later cut off and tied on to the trunk. By the end of October the fungus, as shown in Fig. 120 at the places marked with an *X,* had spread over the broken and dead end of the tip, while the remaining part of the trunk, although *inoculated in the same way, remained perfectly healthy* and continued to grow. The wound due to inoculation had healed normally.

Lüstner quotes similar results from Beijerinck and Rant[4], who could not produce a gummy exudation on peaches and cherries with Cytospora, and report nothing as to the death of the inoculated branches.

Supported by these experiments and my personal observations, I considered not only the disease under discussion but also the others produced by varieties of Valsa, or their pycnidial forms, as occurring with the co-operation of parasites of weakness, in which only the *appearance of disease* was determined by the fungus. The fungi are able to infest the

1 Aderhold, R., Über das Kirschbaumsterben am Rhein. seine Ursachen und seine Bekämpfung. Arb. d. Biolog. Abt. f. Land- u. Forstw. am Kais. Gesundheitsamte. Berlin 1903, P. Parey u. J. Springer, v. III, Part 4.

2 Vuillemin, Paul, Titres et travaux scientifiques. Paris, Typographie, A. Davy 1890, 4o.

3 Lüstner G., Beobachtungen über das rheinische Kirschbaumsterben. Bericht d. Kgl. Lehranstalt, für Wein-, Obst- und Gartenbau zu Geisenheim a. Rh. f. d. Jahr 1905, von Prof. Wortmann. Berlin, Paul Parey 1906, p. 122.

4 Centralblatt für Bakteriologie und Parasitenkunde, Part II, v. 15, p. 374.

Fig. 120. Cherry sapling infected in two places with the conidia of **Valsa leucostoma.** After infection, the top was cut off below the upper wound. At O the normally healed wound. At X pycnids of **Valsa leucostoma.** (After Lüstner.)

branch only when it has become diseased, or at least weakened, as a result of disturbances in nutrition due to atmospheric or soil conditions. On such a foundation no further injury is needed for the penetration of the fungi; this can take place also through the lenticels. The disturbance in nutrition, which must of necessity exist previous to the infesting by such parasites of weakness, is not always necessarily caused by frost. Unsuitable habitat and excess of moisture or drought, etc., can just as well give the first impetus. Lüstner considered the last named factor as the cause of weakening in the cherry trees on the Rhine, while I would rather hold to the theory that, in the majority of cases, injuries due to frost, and in fact those which take place in spring, represent the primary cause.

Accordingly, I see only a very slight consolation in the careful destruction of the parts attacked by fungus. One should not forget especially the ubiquity of the Cytosporeae and similar groups of fungi. The main point is the *cultivation of varieties which have adjusted themselves to a definite locality.* Besides this one should experiment to see whether the sensitiveness to frost can be decreased by an addition of calcium to soils rich in humus.

Branch Blight in Forest Trees.

I judge in the same way, as in the dying of the cherry tree, a disease which Fuckel has observed in apricots and peaches. A characteristic yellowing and wilting of the foliage with a subsequent dying of scattered branches began in June. Fuckel considers *Cytospora rubescens* as the cause and *Valsa prunastri* Fr. as the perfect stage.

Of the better known occurrences of diseases of this character. I will add here *"the black blight of red beech shoots."* According to Willkomm[1] the cause of the dying of the shoots, which turned black at the base, should be sought in a fungus which develops a conidia form like *Fusisporium candicum* Lk. and may be associated with *Libertella faginea* Desm. The perfect stage would accordingly be *Quaternaria Perscoonii* Tul.[2]

The dying of the *pyramidal poplars* which was found in varying intensity through northern and central Germany aroused discussion at the beginning of the 80's in the last century. A similar occurrence had been observed in England between 1820 and 1840[3]. Younger shoots had brown places in the bark under which the wood body also was usually attacked. The leaves became yellowish and limp and the branch died.

Among the different theories which were brought forward to explain the phenomenon, the degeneration of the species through continued sexual propagation played a chief rôle. Although much reference was made, from the beginning, to the fact that a late frost might be taken as the cause,

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1 Willkomm, Die mikroskopischen Feinde des Waldes, 1866, Part I, p. 101.
2 Selecta fung. carp. II, p. 105.
3 Biolog. Centralbl. XI, 1891, p. 129.

which in spring had injured the but little matured branches[1], the theory that a discomycetous fungus *Dothiora sphaeroides* Fr. produced the dying[2] *finally* prevailed. In other places a different fungus, *Didymosphaeria populina,* was made responsible for it[3]. Vuillemin[4] cites *Maminia fimbriata* in the dying of the twigs of the hornbean and *Didymosporium salicinum* as the destroyer of *willow plantations.* Finally we will call attention once more to the dying of the *red alders* described by Appel[5] as due to *Valsa oxystoma,* which fungus can complete its work of destruction only in specimens weakened by disturbances in nutrition.

Freezing of the Spring Growth.

If late frosts surprise the tree at a time when the leaf buds have began to elongate, or have already developed into short shoots, repeated injuries and also phenomena of regeneration will then set in. A case which I have found frequently in cherries shows the dying of the youngest growing point in the opening leaf bud. The injury is not noticeable at first since all the leaf buds have remained intact. After some time, however, a peculiar spreading appears, called forth by the turning back of the very turgid bracts and the absence of growth excites investigation. Later, sickly, lateral shoots appear from the uninjured lateral buds and at times also a fasciated growth after such spring injuries.

I succeeded not long ago in producing the same kind of disturbance by the action of artificial frost. Fig. 121 represents a cherry branch in which three buds have lost their growing points from frost. The vegetative activity, very energetic in the spring, has so made itself felt in the two upper buds that the bract-like, early leaves have become larger, a darker green and fleshier and have spread out from one another almost horizontally. At the lowest bud there is a beginning of two lateral compensatory shoots.

In Fig. 121 *B* the condition of the bud with a frozen growing point is more exactly reproduced. The growing point (*a*) is blackened and dried

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1 The explanation of this disease as a result of frost has been substantially supported by the observations of Count von Schwerin (Gartenflora 1905, Part 5, p. 400). He proved, on an Italian trip, that south of the Alps the pyramidal poplars were not diseased, i. e. no degeneration of this tree could be observed in its present home. Its death, occurring in bands throughout Germany, is explained simply as the result of spring frosts repeatedly occurring at the end of the '70's after long, damp and mild autumns. Of the earlier observers Hausknecht (Bot. Ver. f. Gesamtthüringen; cit. Bot. Centralbl. 1884, p. 275) had already called attention to the fact that the dying showed itself almost entirely in the river valleys and depressions, but spared higher positions. We find another valuable note by Pertsch in St. Petersburg (Deutsche Gärtnerzeitung 1884, No. 10). He found on a trip through northern, western and central Germany that the length of the dead tips became constantly shorter, the farther south he went. The fact that **Populus pyramidalis** is not found in St. Petersburg, while **P. alba, P. laurifolia, P. suaveolens, P. Balsamea,** etc, thrive there shows that it is more susceptible to frost than most of the poplars.

2 Rostrup, Pyramidepoplens Undergang. Tillaeg til Nationaltidende 13. November 1883.

3 Vuillemin, P., Remarques étiologiques sur la maladie du Peuplier pyramidal. Revue mycol. 1892, p. 22.

4 Vuillemin, P., Titres et travaux scientifiques. Paris 1890.

5 Appel, O., Über bestandweises Absterben von Roterlen. Naturwiss. Z. f. Land- u. Forstw. 1904.

and is cut off by a cork layer within the boundaries of the living tissue. In the part of the axial cylinder which has remained alive, however, frost action is shown in the form of horizontal splits in the pith (Fig. 121 *B, l*) and a browning which must necessarily retard its functions as a body capable of swelling. These are the reasons why the axis does not elongate again so quickly. The spiral ducts (*g*) which pass out *into the leaves* (*bl*)

Fig. 121. A. Branch of a sweet cherry. The buds, injured by artificial frost, have thickened and fleshy scales, enlarged and bent away from one another. B. Longitudinal section through an injured bud of the branch.

also appear greatly browned, but the parenchyma (*p*) of the bark body is but little injured and of unusual tenseness. Traces of starch were found here and there at the time of the investigation (June 21). It is clear that the almost fleshy bark body contains an excess of water and nutritive substances and, accordingly, must take over an increased productivity. The greatly increased upward forcing of the water is also to be taken as a cause of the position of the bud bract and the bract-like leaves (*bs*), both

of which have become longer lived through the chlorophyll content of the inner tissue layers.

In occurrences of this kind, frequent in many years in certain localities, it is noticed that, as a rule, the tip bud, which has already advanced farthest in development, can grow on undisturbed. Then the branches have a whip-like appearance, inasmuch as their tips are richly leaved while the lower internodes remain bare. Another phenomenon with which I became acquainted in older pear shoots consisted in a blackening and dying of the basal parts of the young shoots which otherwise still appeared green and did not dry up until later.

Potonié has given special study to the phenomena of the restitution of spring shoots lost through frost[1]. Different varieties of trees behave differently. In many varieties lateral shoots grow from the still uninjured basal buds of the frozen branch as, for example, in *Castanea sativa* Mill. and also in varieties of Celtis and Platanus. If the young shoot is entirely destroyed, a new foliage growth takes place in many plants by the formation of *"accessory sprouts."* Many tree varieties, especially with increasing twig nutrition, form not one alone but a succession of buds in the axil of a leaf by the sprouting of the inner bud stem called *"lower buds."* These "lower" or *"accessory buds"* under normal conditions can develop only on strong shoots of some trees (Cercis). In disturbances, however, as for example, severe pruning, grazing and frost, which destroy the shoot produced from the main bud, they also form the compensatory material in other trees, as for example, in *Calycanthus floridus, Cercis Siliquastrum,* Gymnocladus, *Liriodendron tulipifera* and *Robinia Pseudacacia,* and develop as many as four "lower" buds hidden in the base of the petiole. On the other hand, compensation can also be secured from their so-called "fringing buds" formed the year before. These are the buds in the axils of the basal bud bracts which at times succeed in developing regularly as is perceived clearly in many varieties of willow. If the covering formed by the union of the two bracts drops off, an axial bud is found, corresponding to each half bract and this can form a compensatory branch when the main branch is injured.

In other cases the tree must depend on the dormant buds of the shoots of the previous year for compensation, as may be observed especially with Rhus, *Carya glabra* Mill. and *Juglans rupestris* Engelm, while *Carya amara* Mich. and *Pterocarya fraxinifolia* Lam. chiefly unfold "lower buds." Conifers generally replace the frozen sprouts by the awakening of buds dormant up to that time, and also by a new formation of bud primordia in otherwise budless leaf axils, especially those of the bracts at the base of the annual growth.

No special limitation in the kind of compensation in frozen shoots of different varieties of trees can be made, however, since the strength of the

[1] Potonié, Über den Ersatz erfrorener Frühlingstriebe durch accessorische und andere Sprosse. Sitzungsber. d. bot. Ver. d. Prov. Brandenb. XXII, 1880, p. 81.

frost injury, on the one hand, and the previous nutrient condition of the tree, on the other, together with a greater or lesser ease of adventitious bud formation, characteristic of each variety, call forth different compensatory shoots in different cases. The more luxuriantly a variety grows, the more it inclines to the formation of "lower buds," as can be observed frequently by the breaking of eyes on the main stem.

In grapevines, regeneration takes place from the lateral buds if frost has killed the main ones. This depends greatly on the time of the frost action. If the death of the main bud takes place so early in the year that it has used but very little reserve material in its elongation, then frequently the reserve material still present in the vine is sufficient to strengthen the lateral buds so that blossom buds can still be set. If, however, the main bud dies from a frost in May, strong shoots can develop, to be sure, from the lateral buds, but without setting blossoms. These shoots become fertile only in the next year.

Freezing of Roots.

Not infrequently, especially in wet places after open winters, the roots of very different woody plants are found to have been frozen while the aërial, axillary parts have remained alive. This phenomenon is explained by the fact that the wood of the roots is softer and more porous than that of the trunk. The softness is due, on the one hand, to the fact that, at the time when the cold penetrated deepest into the soil, the growth of the root had not entirely stopped; therefore the frost attacked still young, unthickened elements. On the other hand, however, the already matured elements of the wood body are not so thick-walled as the corresponding parts of the aërial, axillary body. This is universally true without taking into consideration the nutriment and water content of the soil. That the degree of luxuriant development will also exert an influence on the sensitiveness to frost cannot be denied, but this influence, according to v. Mohl's investigations[1], manifests itself differently.

A consideration of the annual range of temperature will give the necessary explanation in regard to the first point, the action of the frost wave on roots not yet dormant.

It should be noted in advance that measurements of the tree's temperature prove the dependence of this temperature in the tree top on the fluctuation in the atmospheric warmth, while the temperature of the trunk, especially at the base and in thick barked varieties, is very considerably influenced by the warmth of the soil[2], since the water, necessarily rising to

[1] v. Mohl, Einige anatomische und physiologische Bemerkungen über das Holz der Baumwurzeln. Bot. Zeit. 1862, Nos. 29, 33, 34, ff.

[2] Breitenlohner and Boehm (Sitz. d. Kais. Akad. d. Wiss. zu Wein, May 17th, 1877) found that under usual conditions the temperature of the lower part of the stem is entirely influenced by soil temperature, but if transpiration is arrested, the temperature of the tree depends entirely on the air temperature.

make up for the evaporation of the foliage[1], has the temperature of the soil layers. R. Hartig[2] furnishes very clear proof of this. The branches were removed from one of two similar trees, on which the sun shone, so that in the current of evaporation they almost came to a standstill. The thermometer then proved a temperature of about 10 degrees lower in the tree on which the leaves had been left than in that from which the branches had been removed. After the removal of the branches of the second specimen, its temperature at once increased about 10 degrees.

Since, in spring, the air body warms up very quickly, it soon increases the direct action of the sun's rays on the branches[3] and keeps them at a temperature at which they can grow. The more intense and lasting the warmth in the air, the more the cambial ring is stimulated so that its production of new wood and bark elements extends from the crown downward until, in April and May, it reaches the roots and then finally causes the production of a new wood ring. The time of the awakening, the thickness of the new wood ring and its maturation differ in different tree species. In fact, an individual difference disappears inasmuch as all specimens are not able every year to produce so much plastic material in the tree top that it will suffice for the nutrition of the cambial mantel of the roots. It then happens that the thickening ring, in such a lean year, extends from the top only to the base of the trunk where it tapers out to nothing, so that the roots in this year do not become any thicker.

The heat wave and therefore the activity of the cambial ring gradually disappear in autumn from above downward, just as they had advanced. Since the soil remains warm longer than the air, the root has still opportunity to continue its growth even if no longer so intensively. This explains v. Mohl's observation that roots in December, January and February are still active in thickening the cell walls of the last formed annual ring.

Definite figures will give the clearest idea of this. v. Mohl found in the winter of 1861-62 that the root formation in a sweet cherry tree had not stopped by the 4th of April. In this the branch buds had already developed a length of more than 2 cm. and the new wood ring in the parent branch had so far matured its new ducts that their pitting was recognizable.

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1 Ebermayer, Die physikalischen Einwirkungen des Waldes auf Luft und Boden. I, Aschaffenburg 1873, p. 119-39. Measurements show that no essential difference exists between the temperature of the trees (breast high) and of forest soil. With increasing depth of soil and height of tree, however, the differences become marked. In general it is found that, from October to March, forest trees are colder than forest soil. "The roots in this period are the warmest part of the tree; the mean tree temperature decreases with increasing height and is lowest in the branches and twigs." "In the summer half of the year (April up to and including September), conversely, forest trees are warmer than the soil, i. e., the temperature of the tree decreases from above downward and, during the day, is highest in the twigs and branches, lowest in the roots." The mean annual temperature of the tree fluctuates between 3.9 to 6.7 degrees according to the elevation in the plane of growth. It is less than the mean air temperature and higher than the mean soil temperature of the forest.

2 Lehrbuch der Baumkrankheiten 1882, p. 177.

3 Compare Krutsch, Untersuchung über die Temperatur der Bäume, etc. Jahrb. d. Kgl. Sächsischen Akad. zu Tharand, v. X, 1854.

The wood cells lying between the ducts were still thin-walled and had only half their typical size. *In the roots, however, the outermost wood cells of the previous annual ring had not once been thickened.* After the tree had blossomed, on the 11th of April, investigation still showed no complete termination of the previous annual ring in the roots and not until the 26th of April did the roots become dormant.

At the time the new annual ring in the branches of the previous year was already completely lignified and so thick that six successive ducts could be counted in a radial direction in the lowest part of the trunk, only a single row of ducts had developed and only the innermost wood cells were found to be thickened. In the main root, the annual ring of the previous year was complete and the cambium already prepared for renewed activity since the bark could be easily separated from the wood body: nevertheless, no traces could be seen of a new wood ring. The bark of the lateral roots, which were as thick as one's little finger, could not be loosened. Thus no complete winter rest was present here. They lingered in this condition until the 30th of April, when some of the leaves were already fully grown and a new wood ring in the main root had begun to develop young, still unthickened ducts.

We will get an insight in regard to the second of the above mentioned points, i. e., the anatomically different structure of the roots, conditioning a lesser power of resistance, if we bear in mind the time when the annual rings in the trunk would be developed in contrast to those of the root.

In the trunk growth, the complete termination of the annual ring will take place so much the earlier in the year the higher it is in the tree top. Consequently its development there will consist chiefly of spring wood. Before the production of the annual ring has extended to the base of the trunk, summer has come and there is not much more time for the development of spring wood. Therefore, the differentiation of the annual ring must so proceed that (no matter whether it is thick or thin) *the relative amount of spring wood to autumn wood decreases from above downward,* i. e., relatively, the autumn wood increases toward the base of the trunk. This hypothesis has been actually confirmed by direct measurements made by v. Mohl[1], as well as by Hartig[2] and Sanio[3]. It should be added here that the thicker the part of the trunk is the higher the maximum of warmth it attains[4].

The firmness of the base of the trunk depends upon the predominant formation of autumn wood.

The character of the tree variety comes into consideration in the development of the root wood. In conifers, with their early termination of root growth, the development falls at a time of greater soil warmth and dryness

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[1] loc. cit.
[2] loc. cit.
[3] Jahrbücher f. wissensch. Bot. IX, p. 155ff.
[4] Ihne, Über Baumtemperatur unter dem Einfluss der Insolation. Bot. Centralblatt 1883, No 34, p. 234. Vonhausen, Untersuchungen über den Rindenbrand. Allg. Forst- und Jagdzeitung, 1873.

and, on this account, chiefly autumn wood is formed. If much material is present, i. e., the annual ring is broad, a strong autumn wood ring has been developed (v. Mohl). In deciduous trees in which the development of the root body is continued until the next year and, in fact, as has been shown above, often does not end before the blossoming time of the next growth, all differentiations are weaker and the boundaries of the annual rings less distinct. Since it becomes spring in the layers of the soil only after it has become summer above ground, spring wood is always formed in the roots. In the further advance of the annual ring, its development depends on the degree and continuance of the soil warmth and dryness. If a year has a long dry period, autumn wood is formed. If this is not the case, development is limited to spring wood, with only a weak beginning of autumn wood formation. Hence the porous structure of the slender *ringed root.*

By briefly repeating what has already been stated, we can summarize the difference between root and trunk in deciduous trees, since first the annual rings in the root are much more slender than the corresponding ones of the trunk and, second, in the constant development of porous spring wood, these slender layers are predominantly porous. In conifers the same difference is found between trunk and root, so far as the slenderness of the annual rings is concerned and, in the same way, the thicker the annual ring the more the autumn wood decreases in proportion to spring wood. The wood cells are everywhere longer and wider and their walls thinner in the roots than in corresponding parts of the trunk.

Therefore, greater attention should be paid to the freezing of the roots because in this is found the explanation of numerous cases of summer death in individual trees and groups among those of the same age and of the same species. Trees with frozen roots, like healthy ones, usually sprout in the spring and often develop normal shoots, even if they bear as a rule smaller leaves. Not until summer, but then advancing especially quickly, does a yellowing of the leaves begin and also a drying of the twigs. The water supply of the trunk is then used up by the transpiration of the leaves.

Even in localities and varieties when no injury of the aërial axis is to be feared from winter frosts, fruit trees in pots should be brought into protected places, because of the sensitiveness of the roots and, in open land cultures, the natural protection from foliage and snow should not only be left but, if possible, increased. In planting tree plantations, it will only be possible to carry out the otherwise advantageous *autumn planting* without danger if absolutely hardy trees are used or the planting takes place so early in the autumn that, preliminary thorough puddling being taken for granted, rooting and a close packing in of the roots in the earth may be assumed. Duhamel[1] observed that a formation of fibrous roots can take place even in winter. This was later substantiated by Lindley. In less

[1] Des semis et plantations des arbres, p. 155.

extensive tree plantations, a deeper penetration of the cold can be prevented by covering the loosened soil. It is a frequent but not universal discovery that the roots of recently transplanted trees suffer more from winter frosts than do specimens left in their original place of growth.

Frost Clefts.

The temperature inside strong tree trunks can follow the temperature of the outer air only slowly and thus the inner part of the trunk is colder than the surrounding air from morning until noon but is warmer in the evening[1]. Then a contraction of the tissues, due to the appearance of cold, will manifest itself in the outer layers of the trunk while the core still retains its original distension. In this way, differences in tension arise which become the greater, the sharper the change in temperature. Now, with a fall in temperature, the wood body contracts more strongly in the direction of the circumference, i. e., tangentially, rather than radially, so that the peripheral mantel of the still warmer core of the trunk really becomes too tight. It must accordingly be stretched tangentially if it shall still entirely enclose the core. If, with increasing cold, it can not stretch sufficiently, it must split. In this way tears are produced in the bark of the tree which advance the deeper into the wood, the greater the cold and the differencc between the cooled peripheral and the warmer central tissues of the trunk. In great, sudden cold, it has been found that some tree trunks crack audibly and then show long, deep gaping splits following the twisting of the wood fibres. Some varieties of trees show this phenomenon especially frequently. The horse chestnut suffers most of all; besides this, the oak, poplar and cherry should be especially emphasized. The cleft remains gaping only so long as the heavy cold lasts. With the appearance of warmer weather the edges of the split approach one another, even closing the wound entirely. The wound, however, is almost never well healed and breaks open again the following winter. The process of healing is normal, since circumvallation rolls are formed from the cambium, the young wood and the bark, and strive to unite. In other injuries with free lying wound surfaces, these projecting overgrowth edges, however, do not find the space necessary for their extension, but are forced to grow directly against one another and to push out over the edge of the cleft wound. They therefore, from mutual pressure, form rolls projecting outward, depressed in the centre like lips, which are called *"frost ridges.'*

In Fig. 122 we see such a frost ridge on a strong trunk of *Acer campestre,* which shows a number of radial clefts. One of these has split through the stem, so that an outwardly visible cleft has been produced which, at the beginning, gaped widely but, with the appearance of warmer weather, has become very narrow. When in spring the tree would have closed the split by growth of the cambial layer, the circumvallation edges

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1 Squires, Roy W., Minnesota Bot. Studies. Bull. 9, 1895.

found no room to grow into the cleft and therefore were forced outward. On this account we find the lip-like processes made recognizable in the cross-section. Such a process of healing has not yet been observed in any other trunk injury, so that its appearance may be considered absolutely certain evidence of frost action.

Caspary[1] has experimentally examined this phenomenon more closely. He proved by direct measurement that the coefficient of the distention of the fresh wood considerably exceeds that of all solid bodies, even that of

Fig. 122. Frost ridge on the trunk of *Acer campestre*. (After Frank-Schwarz.)

iron, tangentially as well as radially, and is exceeded only by air. This explains the sudden production of deep clefts.

The extent to which a cleft opens varies in the same tree species and with the size of the trunk, but all cases show that if the frost clefts have once been produced (even after they have closed in thawing weather) a very light degree of cold is sufficient to re-open them. This is explained by the fact that the amount of strength necessary for the production of the cleft may be sufficient to overcome the cohesion of the cell elements in the whole

[1] Caspary, Neue Untersuchungen über Frostspalten. Bot. Zeit. 1857, No. 20-22. In an earlier treatment, Bot. Zeit. 1855, p. 449, he also cites the earlier literature.

extent of the trunk's radius; with the appearance of renewed cold in the same year, no resistance has to be overcome in re-opening the clefts, and the following winter only enough to overcome the newly formed wound cover.

The frost clefts produced in winter, usually extend deep into the inner part of the trunk. The tree is unable to form a new cicatrization membrane in the older wood and, consequently, each frost cleft represents a persistent, outwardly covered over but inwardly unhealed wound. This becomes the more significant the more some lateral tangential clefts are added to the radial, large frost cleft. These tangential clefts usually extend into the layers of the spring wood and may be connected with one another by radial cross tears. There then occurs an intersected splitting which makes the wood absolutely of no practical use and hastens the death of the tree by facilitating the spread of wood-destroying fungi.

We thus obtain such structures as are shown in Fig. 123, which represents a cross-section through an oak trunk which, infected by *Polyporus sulfureus* from a wound in the branch, has become cleft.

While the splitting of the trunk, due to long clefts, transversing the greater part of the tree shaft[1] has often been described, the production of shorter, shallower clefts, which are more easily closed, has not been sufficiently investigated. R. Hartig[2] considered them in the white fir where they are often very shallow, appear in the upper parts of the shaft and usually coalesce very soon without forming frost ridges. Also, they follow the direction of the wood fibres, i. e., usually somewhat at an angle. Besides occurring in the fir, I find this kind of short frost clefts often with a lip-like wall in the red beech, the cherry and the plane tree. Curiously enough, these varieties are distinguished by a bark which remains smooth for a long time. In this, the preference for certain sides of the tree, in the production of frost clefts, is most easily perceived. If the trees are not accidentally protected by adjacent ones but stand free it is possible in the majority of cases to determine that the west and southwest sides display the most abundant injury from frost. Street plantations of plane trees, for example, show how differently the different sides of the trees behave. At the time when the well-known, normal dropping of the bark scales from the trunk begins, it will be found that most of them are thrown off first on the southwest side of the trunk.

At times *"tears due to drought"* are described as frost tears. Nördlinger[3] has called especial attention to this. Tears due to drought, which occur especially in strong trees growing on an impervious soil layer, or undergoing a sudden great scarcity of water, are characterized by repeated

1 Göppert, Über die Folgen äusserer Verletzungen der Bäume, p. 30, Breslau, 1873. He found frost tears in 76 different varieties of trees.

2 Hartig,, R., Lehrbuch der Pflanzenkrankheiten, 3d edition, p. 214, Berlin, 1900, Julius Springer.

3 Nördlinger, Trockenrisse (falsche Frostrisse) an der Fichte. Auch ein Grund der Rotfäule. Centralbl. f. d. gesamte Forstwesen. Wein 1878, Part 6.

changes in their radial course in the older annual rings, than in the younger ones, or by the radial splitting of one or two annual rings in the wood disc. Such inner clefts then have the form of a lance tip, i. e., are broadened at the centre. Since in clefts extending to the bark the wound remains open, the circumvallation walls incline toward the cleft and, therefore, form no projecting ridges in frost clefts.

Fig. 123. Oak stem cleft by **Polyporus sulfureus.** (After Frank-Schwarz.)

Frost Blisters.

In connection with frost clefts, the so-called "*internal frost tears*" should be considered, which R. Hartig[1] has observed in oaks and firs.

"If the tree shrinks with great cold"[2] he says, "tears can arise in the wood body on the surface of the cleft which, however, extend only to the bark mantel *without* splitting it. The bark, which has no radial cleft surfaces, holds the wood body together. However, the elastic bark of the fir

1 Hartig, R., Innere Frostspalten. Forstl-naturwiss. Zeitschr. 1896, p 483.
2 Lehrbuch der Pflanzenkrankheiten, 1900, p. 214.

is distended where the frost tear opens internally and thus loses a part of its elasticity. If the tree later grows thicker, the bark exercises a lesser pressure on the cambium at this place and the additional growth is, therefore, locally increased. Outwardly the trunk is not round but has ridge-like processes."

I assume a very similar course in the production of the structures, which I term *frost blisters*. These are broadly conical, but usually flattened processes at times one centimeter high on the smooth bark of trunks or branches two or more years old.

These blisters should not be confused with the conical bosses, occurring not infrequently on luxuriantly cultivated varieties. In them a *hard wood core* is recognized immediately under the bark, while the frost wood blister, in some cases, consists permanently of a soft tissue mass, easily indented with the finger nail which, in other cases, lasts only during the year of its production.

The projections, strongly lignified from the start, and for which I would like to propose the name of *"duct boss,"* almost always have a definite position in relation to the bud, while the frost blisters are found on any part of the young trunk or the branch internode. "Duct bosses" are bark covered, wood swellings with one or two points, which, like the beginnings of a gnarl, project above the periphery of the rest of the wood body. They owe their production to the excessive development of the two vascular bundles which normally pass into the bud cushions and unite with the central, strongest bundle of the vascular bundle body of the petiole.

In the tender frost blisters we find no connection with the cords of the leaf spur. They are found at any place and arise from a blister-like distention of the bark body away from the wood cylinder. The young wood, lying on the wood cylinder, at once begins cell increase, since the distention takes place only in late frosts and, therefore, at the time of growth activity. This young wood fills the cavity with a thin-walled parenchyma wood which gradually passes over, at the periphery, into normal wood.

The whole process taking place here is the same as occurs in the new formation of bark on an artificially produced wound surface. In blister formation the difference lies alone in the fact that the bark does not scale off, but is only raised in places by the frost and that thereby the new structures, lying above the wood body, at first do not become visible to the naked eye. At times they can be very clearly recognized by their unusual luxuriance when the bark is cut on large frost blisters. It is then possible to expose here and there a wrinkled outgrowth, several centimeters long and 0.5 to 1.0 cm. high, which is not connected at all with the old bark and only rests on the wood body. In one case (in the pear Bonne Louise d' Avranche) the outgrowth had ruptured the bark mantel and had extended far beyond the circumference of the trunk as an irregularly outlined, somewhat conical mass with a warty, crumbly surface.

I could observe other stages of healed frost blisters in the maple and the apple. As yet the best examples have been found in the maple, and, in fact, on two year old shoots, more than 1.5 m. long. Many of these, in their whole course, excepting the tip region, and on all sides, showed small flat, completely bark covered bosses, possibly 0.5 mm. high which were more noticeable to the touch than to the eye. The outer bark appeared perfectly normal and the direct continuation of the remaining, not roughened part of the branch. In cross-section, the cause of the out-pushing of the bark may be recognized in the swelling of the wood body which, at the beginning of the second annual ring, has formed an aggregation of parenchyma wood cells very broad and rich in starch. As a rule, such an aggregation of wood parenchyma is found lying exactly between two medullary rays so that the lateral transition from this diseased wood tissue to the healthy tissue is rather sudden, while the abnormal wood elements assume very gradually in a radial direction the normal dimensions and thickness. Only in the radially and laterally adjacent wood with a regular structure are found greatly widened and shortened wood cells filled with starch (investigated in May).

In the wood parenchyma aggregations, irregularly extended, yellow stripes are found; the yellow color arises from swollen cell walls which are universally present in frost injuries. Also, other characteristics of a definite group of frost injuries are present as, for example, the *lateral displacement of the medullary ray cells* at the frosted place and the barrel-shaped widening of the medullary ray where it enters the parenchyma aggregation. This barrel-shaped widening of the medullary ray is produced less often by the increase of its cells than by their broadening at the expense of their length. In this, not infrequently, a very striking thickening of the secondary membrane is noticed. Cell increase is found most frequently in the one-celled medullary rays which, from the point injured by frost, become two-celled. The further such a medullary ray extends into a parenchyma aggregation, the broader and shorter its individual cells appear in cross-section and with relatively more slanting walls; they dovetail into one another, instead of remaining bluntly placed against one another. At last the shape of all the cells in the parenchyma aggregation, of which the elements are widest near its centre, become the same so that no difference can be recognized in the medullary rays.

A brown bark zone, tangentially elongated, which was formerly connected with the parenchyma but is now separated by newly interposed wood, corresponds in the same radius to the yellow or brown striped aggregations of parenchyma wood.

By coloring the section with campeche wood extract, very interesting pictures are often shown, if a concentrated solution of chloriodid of zinc is added. The difference in thickness in the walls of the wood cells becomes more apparent. The walls of some groups of wood cells are colored more intensely yellow and are more swollen.

These were the *walls of the radially divided wood cells*[1] *surrounding the ducts and containing starch which, therefore, might be more sensitive* than the other elements of the vascular bundles.

In frost blisters of the cherry, illustrated in Figs. 125 and 126, the anatomical structure evidently differs from that of the frost blisters of the maple branch, inasmuch as here the gummy exudation usually sets in as a result of the injury. Fig. 125 is a cross-section through the centre of a blister. Fig. 126 a longitudinal section made at one side of the medial line of the wound; *r* is the brown stripe of dead tissue which immediately bounds the inner, fine tear which caused the blister. This tear was not visible externally since the outermost bark layers (*e*) had remained uninjured, although the wound was deep and extended to the old wood (*h*). It must from the beginning have been very narrow, however, and produced at a time when an immediate overgrowth was possible since the overgrowth tissue had sunk at once into the wound (*r*) without causing the death of

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[1] If, at the time of the awakening of vegetation, cross sections of Acer, **Salix viminalis,** and other trees are treated with a strongly acid, concentrated solution of chloriodid of zinc, large dark blue, variously shaped starch structures may be seen to pass out from these radially divided wood cells (compare Fig. 124 r). The forms of these are different. At times they may clearly be seen composed of separate, irregular, swollen starch grains because the cores, remaining firmer, appear granular on the smooth upper wall surface of the pouch-like structure; they are left after the dissolution of the peripherial layer of the starch grains. At times, however, the substance of the hollow body is uniformly membraneous and the upper surface smooth; the tip often appears notched. In older wood such starch structures appear most numerously in the autumnal wood of the last two annual rings. Glycerin clears up the starch pouches which occur on the upper side as well as the under side of the section. Alcohol brings out their contours more sharply and makes them seem darker. Potash bleaches them and shows better the granular elements of the walls. Their formation seems to result from the swelling of the starch grains which they rupture and, with the reagent, transform their contents into a membrane in which, at times, bright circular spots may be seen, just as if vacuoles had been deposited during the formation. The notched form of the tip is conditioned by the irregular pushing forward of the individual, outermost starch grains. I would like to consider these structures Traube's cells; strongly acid chlorzinc with potassium alone showed a membraneous precipitate. Tin-chlorid (neutral) and iron chlorid (acid) produce no such structures. They are also not destroyed by sulfuric acid or hydrochloric acid. A drying of the branches which had previously displayed many such structures, decreases their formation or stops it entirely. This phenomenon can not always be produced. It seems to be connected with the special constitution of the starch shortly before its dissolution in the early spring.

Fig. 124. Starch structures formed in the treatment of sections of a young willow branch with chloriodid of zinc. They pass out of the bisected wood cells and often curve into the duct lumina.

considerable amounts of tissue. This young tender overgrowth tissue, as well as the cells bounding the diseased parts of the bark, at once produced thick bark layers (*kn*) which completely encased the dead tissue and isolated it from the healthy tissue. The hard bast bundles (*b*) which, in the midst of the healthy bark tissue, became diseased immediately about the wound, had been enclosed by isolated cork circumvallation (Fig. 125 *u*) so that from them no further decomposition of the surrounding bark parenchyma, containing chlorophyll, could take place.

In the process of healing, the new wood (*n h*) and the new bark (*n r*) endeavor to cover the wound, beginning at the sides and extending inward.

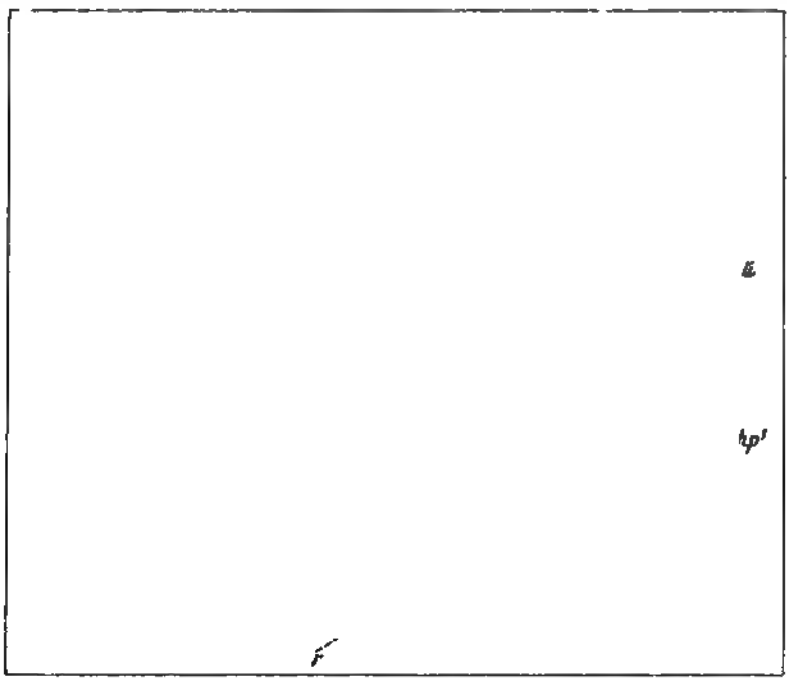

Fig. 125. Frost boil on a branch of sweet cherry. Medial section.

In the centre of the wound, where the gaping edges stand further apart (Fig. 125 *n h*) no closing has yet been possible. On the other hand, this is the case at the sides. The edges of the two new wood layers (Fig. 126 *n h* and *n h'*) have become united and the dead piece of the bark (Fig. 126*u*) is separated from the dead piece of the wood. The older and thicker the new wood and bark layers become, the more the dead bark is pushed outward and finally pushed off. The dead wood (*h p*), of a parenchymatous nature, and the momentarily fresh wound edges (Fig.. 125 *h p'*), likewise formed of parenchyma wood, at first gradually pass over into firmer, normal tissue. The first formed new wood, suitable for circumvallation, bears in itself, in the central wound region, the germ of death; numerous gum

centres (Fig. 125 *g*) have been formed, which in a short time will dissolve the less resistant tissue.

In older circumvallation on a maple branch, which was not at all luxuriant, a *splitting of the annual ring* was noticed, since the region of the autumn wood on one side of the branch was divided into two parts by a considerably thicker zone of spring wood, rich in ducts, and then reunited with the zones first formed so that one more annual ring could be counted on one side of the twig than on the other.

When such excrescences are remarked for the first time in trunks which, up to that time, had been healthy (this is the case in the early summer months) it will be advisable to strongly scarify the tree. The knife could be inserted above the excrescence and several long cuts be made through the blister into the healthy underlying tissue. By the wound stimulus thus

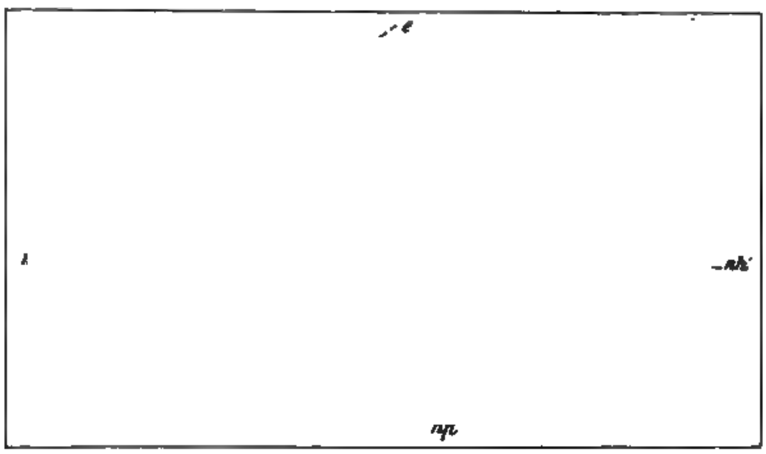

Fig. 126. The same wound as in Fig. 125. A lateral section.

brought to bear on the healthy tissue near the blister, it is incited to an increased circumvallation activity, and the pressure of the diseased excrescent tissue on the plastic underlying material is reduced.

Frost Wrinkles.

While the raising of the whole bark body from the wood cylinder found in places in frost blisters could be proved to have been their cause, in frost wrinkles a loosening of the outer, coarser bark layers from the tender, inner bark is concerned. The phenomenon has been observed as yet only on the new growth of cherry branches in June. The branches were conspicuous because of the coarse wrinkles on one side of the otherwise smooth bark. The cambium was not disturbed, the pith was somewhat browned.

As has been proved, a penetrating frost produces great differences in tension in the trunk. The frost, without necessarily forming frost crystals

in the intercellular spaces, contracts the tissue, and so much the more the thinner walled the tissue is. The bark suffers considerably more than does the wood which, reached later, cools down less easily and contracts less. The tangential contraction is greater than the radial. This difference acts likes a one-sided strain, taking place in the direction of the circumference of the trunk to which the different layers of the bark will respond to a different degree, when the bark, as a whole, is very young. With an equal amount of contraction at all points in the bark, the cells lying nearest the periphery and most elongated in the direction of the circumference of the trunk, will be most displaced. If one considers that the outer cells of the primary bark, because of the great coarseness of their walls, are not as elastic as the underlying, thinner-walled ones, it is clear that, when the strain ceases in them the permanent increase, caused by the incomplete elasticity, will be the greatest.

After the frost action has stopped (it continues only a short time in late frosts) the increased turgor will cause the cells to retain their distended form and, since the outer, greatly distended bark layers no longer have sufficient space in the previous tangential plane, they become raised in wrinkles or blisters above the plane of the circumference of the trunk and in this way form "frost wrinkles."

Besides the tangential and radial contraction, there is an additional, longitudinal change in the young, still herbaceous twigs, which must be produced with the twisting of the axillary body, caused by the frost action. One can easily produce cross wrinkles artificially on one year old shoots by bending them. Reference should be made to a work by Ursprung[1] in regard to the tensile conditions developing in bent, herbaceous stems.

Bark Tatters and Cork Holes.

The loosening processes which set in after a drying of the outermost tissue layers when the branches have been killed by frost occur more frequently than the phenomena of raised bark, appearing in the form of frost wrinkles and blisters in living bark tissue. In Fig. 127 is shown a branch with loosely rolled back, flapping, dry bark tatters on the autumn (Sylvester) pear. Even in the soft wooded apples (Morning Breath) the phenomenon was found in May and June, on branches and young, still smooth barked, sapling trunks. The periderm is seen at first to be distended in blisters; later the blisters split longitudinally. The whole bark parenchyma underneath the tear seems blackened and dries up quickly. The death of the bark tissue advances further, the more the tear widens, since it at first becomes yellowish green and tender, then grows dark, collapses and finally dies.

In time these dead spots become entirely bare, since the longitudinal tear in the periderm blister lengthens and new cross tears divide the whole

[1] Ursprung, A., Beitrag zur Erklärung des exzentrischen Dickenwachstums an Krautpflanzen. Ber. d. D. Bot. G. 1906, Part 9, p. 498.

raised cork into many tatters. In drying, the various tatters curl backward and thereby expose the bark parenchyma which has been covered. It should also be observed that such cork tatters are most frequently found directly at the base of the young, still smooth barked trunks, while the younger shoots seem outwardly unaffected and also sprout but, yet, after some time, the leaves turn yellow and wilt.

The life of the tree depends on the extent and frequency of such holes in the cork which are found repeatedly separated from one another by healthy spots. The tree usually dies since the cambium under the blackened parts of the bark is dead. The region near the buds or near cut branches seems especially disposed to such injuries from frost.

The Phenomena of Discoloration in Trunks and Branches

Fruit growers in spring pruning usually decide after a consideration of the cut surface, whether a variety of fruit has proved hardy for a certain region, or has been injured by the cold. The decision is made according to whether the cut surface is uniformly white or browned in places. The browning sometimes occurs in circular zones, sometimes in flat surfaces. In the first case (often on one side of the branch) the cambial region, or the periphery of the pith disc, the so-called *pith crown* where the innermost ducts of the wood ring penetrate into the pith parenchyma, is the centre of the discoloration. In the surface browning, a part of the wood surface together with the pith body is usually attacked on that side of the branch where the bud lies which belongs to it. The discoloration is a sign of the humification which sets in gradually in the walls when the cell contents dry up. Not infrequently phenomena of swelling are noticed in the brown cell walls.

Fig. 127. Raggedly torn cork lamellae on branches injured by frost.

If different parts of the trunk are frozen, brown stripes are found at times extending downward to different depths in the wood body; in the browned parts through its whole diameter. These stripes often have a symmetrical arrangement so that a cross-section through the semi-healthy

part of the trunk shows a regular, brown figure. Most well-known is the "*Landwehr cross*" in the maple and similar structures in Cytisus and Fraxinus. Cytisus and other Papilionaceae show at times a very attractive bright coloration of the cross-sections which should be made of practical use. The bright coloration is caused by the different degrees of browning in the heart wood and cambial zones.

Such regular, surface-like discolorations are of rare occurrence. The most frequent phenomenon consists of an irregular browning of those parts of the bark which surround a bud and of those outcurvings of the pith which lead to this bud. The amount of tissue disease naturally depends upon the time and intensity of the action of the cold as well as the specific sensitiveness of the variety and, with equal intensity, on the age of the axis. As a rule, the younger a branch is, the more extensive is the tissue browning.

The cross-section, shown in Fig. 128, of a pear branch injured by artificial frost, gives an insight into the variety of browning due to frost. In this, *m* indicates the pith body, *m k*, the pith crown, *m b*, the outcurving of the pith disc, called *pith bridges*, which lead to the bud, lying close above this section but not visible in it. At the place where the bud lies, each stem is more or less thickened and pushes out from a "*bud cushion.*" In this bud cushion lie also the vascular bundles *g'* and *g"*, which pass downward into the petiole, in the axil of which is found the bud. The cap of tissue, which, in the drawing lies above the central cord of the leaf spur, and seems laid against the bark body of the twig, represents the cicatrization tissue which had formed in the previous year after the falling of the leaf. The different ducts in the cords of the leaf spurs and in the wood ring are distinguished by *g,' g"* and *g*. The wood ring (*h*) with the medullary rays (*m s*) shows diverse, predominantly radial clefts, while the tissue openings (*l*) in the bark tissue usually extend tangentially. Noteworthy is also a gaping, longitudinal split which breaks the pith bridge and, by the amount of injury, makes apparent that it represents the part of the branch most susceptible to frost.

In many deciduous trees there is still a second region of great susceptibility to frost, viz., the hard bast cells and their outer parenchymatous covering. In my experiments with artificial freezing, cherries, plums, red beeches and apples were proved especially susceptible, while pears showed a greater power of resistance. In the adjoining picture the bast bundles (*b*) are found to be unattacked. Just as little is the collenchyma (*cl*). The cambium zone (*c*) which, by its brown color, indicates to tree breeders in the spring pruning of fruit trees that the branches have been injured by frost, has not been browned in the pear. In microscopic investigations, it is found that usually the still cambial, thin-walled, young wood and the innermost young bark, of the same age, have been browned, while the meristem layer, rich in cytoplasm and lying between both regions, appears colorless and uninjured.

By surveying the cross-section as a whole, which may serve as an example of frost discoloration for all trees, we see that the region of *the bud cushion is the most susceptible part of the branch.* In this region the twig

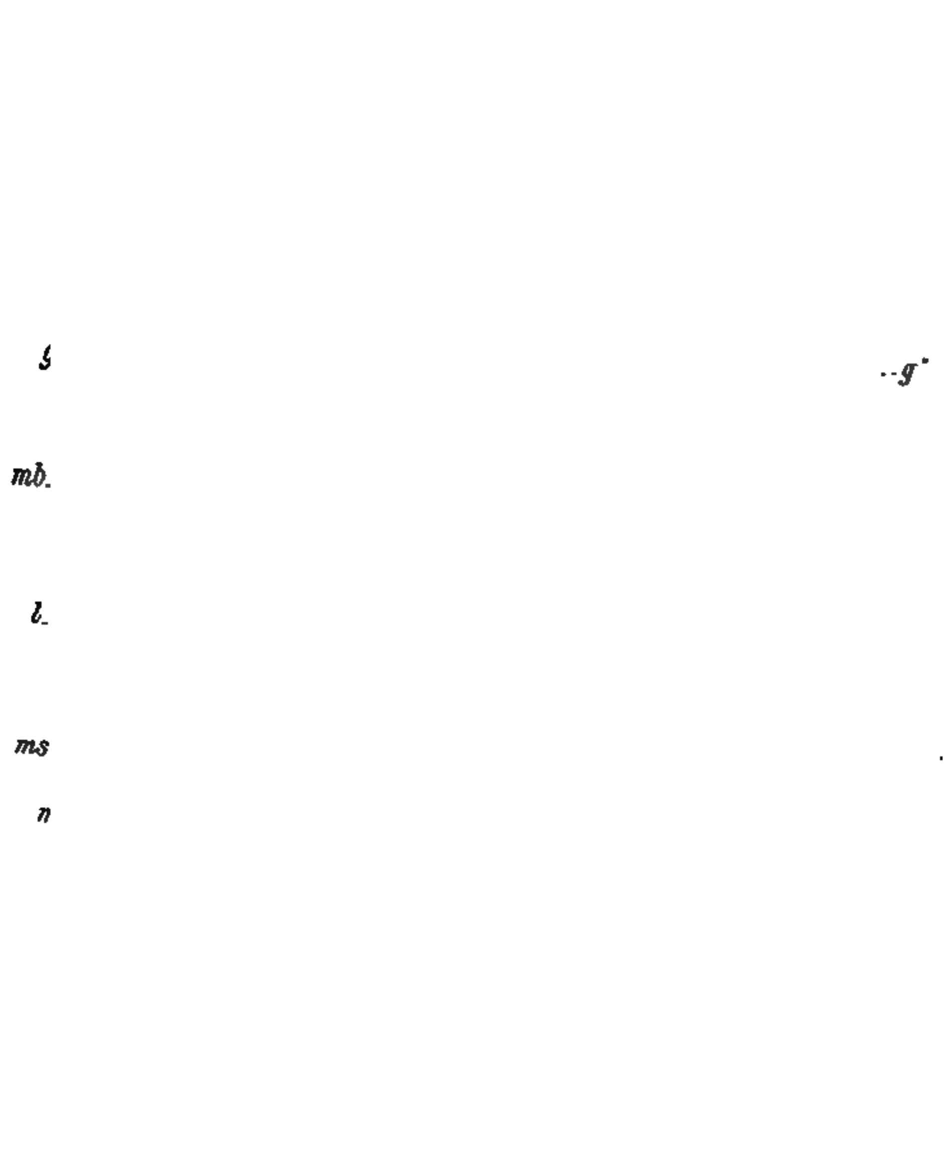

Fig. 128. Browning and splitting of the tissue of a pear branch produced by artificial frost.

has the slenderest wood ring and the largest accumulation of parenchyma. The spots kept dark in the drawing represent the browned parts. So far as susceptibility is concerned, the pith crown and the medullary rays follow

next. The pith body itself usually does not suffer until later and the older the branch is the less is the injury to the pith body. In the present case, the experiment was carried out toward the middle of May, at which time the storing of starch had already taken place in the pith and bark. The injury to the pith was limited here to a checkered marking of the pith disc, while the contents of some of the cells containing starch had turned brown. Investigation showed that the cytoplasmatic substances, and not the starch grains themselves, were discolored.

The irregular distribution of cells browned by frost in all tissues can be explained only by the different cell content. Probably cells rich in sugar are the most susceptible. The cytoplasmatic content has suffered even when the cell membrane is still clear. In injuries to the pith crown the narrow, spiral ducts are the first ones to be browned.

The Frost Line.

Mention was made in the previous section that the fruit grower usually considers the browned cambial region as an indication of frost injury. This zone is now often termed *"frost line."* Even unskilled forest workers showed me, as frost lines, the circular zones, setting in after spring frosts, between older annual rings with which we will later become better acquainted in the discussion of "false annual rings" and "moon rings." By these terms are understood the brown circular, or zigzag stripes found by testing microscopically the tissues injured by frost. These stripes are composed of collapsed misshapen parenchymatous cells, and occur very often but as yet have been but little studied. I have investigated more exactly the phenomenon on branches of an apple tree which had been forced in a greenhouse and then, in May, exposed for only 22 minutes to a temperature of 4 degrees C. below zero.

By the middle of June, in the experiments carried out on a branch of which the tip was frozen, a sharp boundary was found between the dead part and that which had remained alive. This observation is confirmed in all frost injuries. A *gradual extension* of the injured zone *does not* become noticeable subsequently, if no secondary factors, such as wood-destroying fungi, enter into co-operation. However, the action of the frost itself can radiate out into the healthy tissue in the death of certain parts as was the case in the experiment under consideration. If the branch which had died after its tip was frozen was cut off directly below the bud which, adjoining the dead tissue, had remained healthy and had sprouted, a browned, sharply defined stripe was found to extend from the dead places out into the healthy part of the axis past three healthy buds. This stripe traversed the axis in a diagonal direction from the outside inward.

The sharp limitation of the brown stripe and its diagonal course were explained by a microscopic investigation. This proved that the main vascular bundle of the lowest dead bud of the frozen tip is involved here. This was, therefore, a case where *the death of the bud gradually induced*

the dying back of the conducting cord (vascular bundle) which traversed the healthy tissue and the tissue which became diseased. This, therefore, could be the only after-effect which can take place in frost injuries in case there is no subsequent parasitic infection.

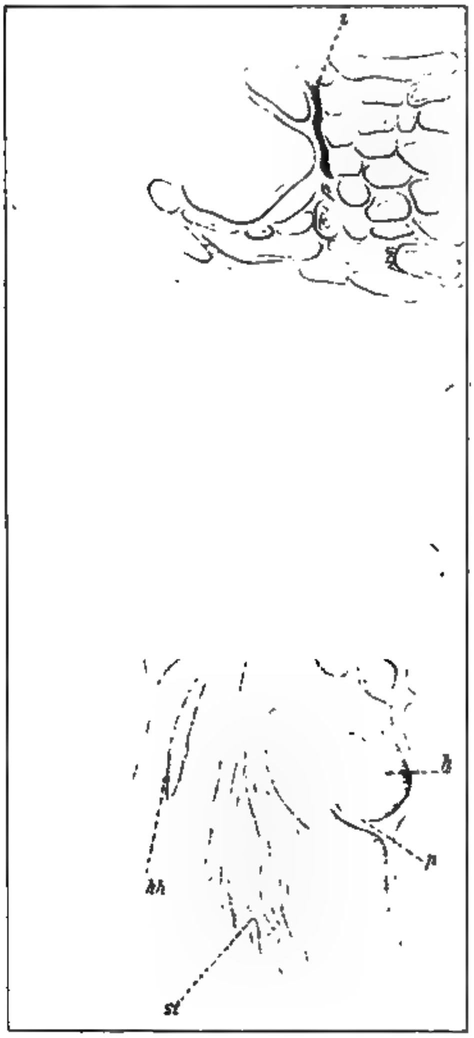

Fig. 129. Swelling of the cell walls after artificial frost.

In order to discover which might be the very first effect of frost on the tissue of the tree and, therefore, which injury sets in with the appearance of very light frosts, a whole course of experiments was made on the effect of slight degrees of cold, but they did not lead to the desired results. Either no effect at all was shown or the above-mentioned initial stages appeared simultaneously. The pruning was extended further and further back from the completely frozen tissues into the healthy, basal part of the twig and observations were made to see which disturbance had extended farthest from the frost centre into the healthy tissue.

The frost action which could be traced farthest into the healthy *wood was found to be the swelling of the intercellular substances, i. e., the middle lamella* (Fig. 129 *i*).

I found this striped swelling and browning of the intercellular substances to be in general more frequent tangentially than in the direction of the medullar rays, especially often near the old autumn wood, i. e., in the first vascular layers of the spring wood. But this condition of the intercellular substances is rarely found by itself; it is usually associated with a slight yellowish coloring and swelling of the secondary membranes of the adjacent wood cells (Fig. 129 ***h***). In some cases this change becomes so extensive that the entire cell lumen is filled, excepting a narrow cavity (***hh***).

The power of refraction becomes extraordinarily weak with the swelling, being retained only by the outermost membrane and the firmer, inner

lining. The swelling can become so great that even the outermost membrane tears (*p*) and this tearing, as a rule, extends to several adjacent cells, so that the changed secondary membrane with the swollen intercellular substances, coalesces into a uniform yellowish to brown stripe in which are recognizable parallelly deposited remnants of the primary membrane (*st*).

It has thereby been proved experimentally that *processes of loosening are initiated in the cell membranes by frost.* These become apparent in the so-called "frost lines."

Internal Splitting of the Trunk and Branches.

In the section on frost blisters, the disturbances were considered which take place in smooth barked branches and trunks without any external injury being noticeable at first. Not until the year following the production of the blister do the primary bark layers, which cover the frost blister, rupture because this blister has gradually enlarged. These torn bark layers surround the protruding new structure as dried edges. The cause, however, is to be seen only in the raising up of the *bark layers,* without any splitting of the wood.

If, however, the occurrence out of doors in so-called frost holes, i. e., places where late frost occurs almost annually and very extensively, is more closely examined, blister-like protuberances will be found on the branches and trunks which internally show repeated splittings of the *annual ring.*

I have accidentally succeeded in producing such blisters artificially by exposing to sharp brief frost action branches in which the wood ring of the current year had attained a considerable thickness. The subjoined Fig. 130 represents a healed inner wound, due to the splitting of a cherry branch. The frost wound has been produced by a one-sided raising of the bark from the young wood. *a* is the old wood of the previous year; *b,* the spring wood of the current year, formed before June; *g* is the sapwood region with the normal cambial zone. About this time the branch was placed in a freezing cylinder. It was found, in the subsequent investigation, that the bark had been split off from the sapwood in a wide curve (*s p*) and that the young wood (*b*) seemed split radially. The splitting extended along the medullary rays which more rarely were torn apart than loosened at one side from the prosenchymatous cells and ducts and then partially dried up. A radial enlargement of the holes represented at *o* in the drawing takes place in many cases because of the extensive drying of the prosenchymatous cambial elements which are still partly thin-walled. In general the radial clefts in the wood remain slender and only the walls of the elements which drew apart from one another turn a deep brown.

Near the breaking buds in which a medullary bridge traverses the whole wood body from the pith to the bark in all trees, the tissue is more tender, the number of thick-walled cells is less; the elements lying next to

the medullary rays have developed into wood cells with strongly refractive walls, while the cell forms, to be found at a further distance from two medullary rays, are still thinner-walled and richer in content, also showing no broad ducts between them. In such sapwood layers, near the bud, a tangential clefting of the tissue on the line between the wood of the previous year and that of the current year is found at times as the continuation of the radial split.

Radial holes (*l*) in the tissue of the secondary bark (*n*), correspond to the clefting of the wood body, while the primary bark (*m*) with its hard bast bundles (*h*) shows no ruptures whatever but only a partial browning

Fig. 180. Internal splitting of a cherry branch produced by artificial frost.

of the contents and of the walls of some of the hard bast cells and bark parenchyma cells (*r*). Here also the holes are produced often by the separation from one another of the different tissue complexes, less often by the splitting of the membranes of the individual cells. The thin-walled cell groups which, in the secondary bark, correspond to the bast parenchyma of the primary bark, separate from the bark rays which have already advanced further developmentally and are, therefore, thicker walled. At the sides of these bark rays the rows of cells, accompanying the hard bast cords and containing calcium oxalate, are especially noticeable.

The radial splits and clefts, however, are only secondary phenomena in comparison with the great tangential clefts (*s p*) which separate the bark

from the wood. The line of separation extends irregularly, sometimes in the cambial layers of the bark, sometimes into those of the sap-wood. Since it can be assumed that in all parts of the tissue of the line of separation an equally strong strain was active in producing the tear, it is evident, from the irregularity of the line of separation, that the tissue at the same radial distance from the centre of the branch does not possess throughout the same firmness. Such an irregularity is shown by the tissue fragments (*k*) which, remaining attached to the sapwood, die later and are indicated at the side of the projecting wood (*f*).

With the exception of these fragments very little collapsed tissue is found at the torn place, even the cells of the youngest bark (*n*), which have turned a deep brown and become poor in contents, have not collapsed. Instead they have become stiff and their walls (*i*) much more resistant to sulfuric acid.

The healing of such wounds does not as a rule take place by lateral circumvallation. Rather, in similar places, a radial stretching of the older cambial parenchyma is observed at first. Later isolated meristemic aggregations are produced in the bark between the bark rays which form new wood elements. The new wood gradually presses the tissue layers (*n*) which, in this case, have not been changed, against the split sapwood in the direction *f*, *o*, *e*, and forms from the dead tissue remnants a brown stripe which becomes narrower with a greater wood accumulation above the place of rupture, i. e., greater pressure. The isolated meristemic zone of the *wood bundles, produced in the raised pieces of the bark,* later unite laterally with one another and, finally, with the cambial zone (*f*), produced on all sides of the still uninjured branch. Such a blister, produced by tangential raising and radial splitting of the wood ring, may remain recognizable externally for many years.

Open Frost Tears.

An apparently very unessential phenomenon, to be found most easily in vigorously growing nursery specimens, is the occurrence of small tears which have been overgrown. These extend also, more or less like blisters, above the smooth bark but are distinguished from those already described in that they have a long grove on their upper surface. From this it is evident that they have been produced by the coalescence of the two edges of wounds which have pushed forward like lips. These elevations grow less and less conspicuous with later growth and finally have no further significance for the life of the trunk.

These are, however, of uncommon theoretic importance in explaining the production of the tissue excrescences described later as *frost canker.* So far as my investigations have gone, they support the theory that the swellings of frost canker have their origin in such small tears as are produced in the spring at the time of the most luxuriant cambial activity of the trunk. Such tears are found usually in the immediate proximity of the

buds and their appearance can be traced back primarily to a local increase in growth. It cannot be denied that this is the most pertinent explanation, but the condition of the wound in many cases also indicates some frost action.

It is finally possible, in artificial frost experiments, to produce such frost tears and thereby put an end to such doubts. Fig. 131 gives the

Fig 131 Cross-section through the bud cushion of a larch branch, injured by artificial frost

anatomical appearance of such a wound which had been produced by the action of artificial cold on a larch branch a year and a half old. The branch was cut through a bud cushion; the wood (*h*), which otherwise would have formed an uniform ring about the pith (*m*), appears interrupted by the broad parenchymatous medullary bridges (*m-mtr*).

This tissue has been killed by frost and torn by the subsequent drying. The parenchyma, lying in the direction *v-va*, had not been formed at the time of the frost action (May 18th), but the splitting of the medullary bridge was extended outward through the bark. The bark in the cambial zone at that time was also split away from the sapwood at both sides and formed the split (*s p*) but only the cells lying directly on the edges of the wound had died and partially dried. The two sides of the bark above the split (*s p*), which originally had been separated, at once formed the initial stages of the overgrowth edges in the manner common to all processes of circumvallation by the outcurving of the peripheral healthy cells and their division. These overgrowth edges are formed further and further out toward one another until in a short time they coalesce.

The place of coalescence of the circumvallation edges (*n r*) may be recognized by the diseased depression (*v a*), but especially by the position of the hard bast cells (*b*), which seem inclined toward one another. The whole tissue, which covers the split, has been formed anew in the course of six weeks (the wound was investigated on the 4th of July). The old bark, which had been split by the frost tear, is pressed back by the lip-like, protruding circumvallation edges and now surrounds the new structure like a sharp edge (*t*). The circumvallation edge at this time had formed wood. The whole thick-walled zone (*hp*) is new wood. This, however, has been produced with so little bark pressure that it has become parenchymatous and short celled. Only later did the cambial zone (*c-c*), produced by the coalescence of the zones, which had been isolated in two halves, form normal wood elements and deposit firmer layers about the frost wound.

Similar to this injury to the larch is a wound produced on an apple branch by the action of cold at 3 degrees C. which lasted for 25 minutes in July (Fig. 132). In this, *a* indicates the old wood of the previous year; *b*, new wood formed up to July; *c*, the region in which the cold had killed the tissue. In the very luxuriant overgrowth edges, extending above the surface of the wound, the spirally curved cambial zone (*f*) has produced a thick new bark (*g*) and a new wood body (*e*), divided radially by the medullary rays (*d*). But this formation of wood from prosenchymatous elements begins first rather far back in the circumvallation edge. The lip-like part of the edge, lying in front of it, consists of parenchyma wood, on the edge of which may be recognized gradually differing prosenchymatous cell groups (*h*). In the same radius, in which the first thick-walled wood cells occur, the beginnings of the hard bast cells (*h b*) appear in the bark.

The circumvallation edges extend over the bark as a knob with a lip-like cleft. This appearance is retained because of the natural swellings which are met with at times in the branches from cankered trunks of apple, beech, ash and cherry trees, and which I consider to be the initial stages of the closed canker swelling (cf. Fig. 135 in the following section).

Canker (Carcinoma).

As "canker," I consider those wounds which develop their overgrowth edges into excessive wood swellings. The character of the excrescence lies in the *exclusive, or predominant formation of parenchyma wood* instead of the normal prosenchymatous wood elements. The canker excrescences have a typical form for each tree variety.

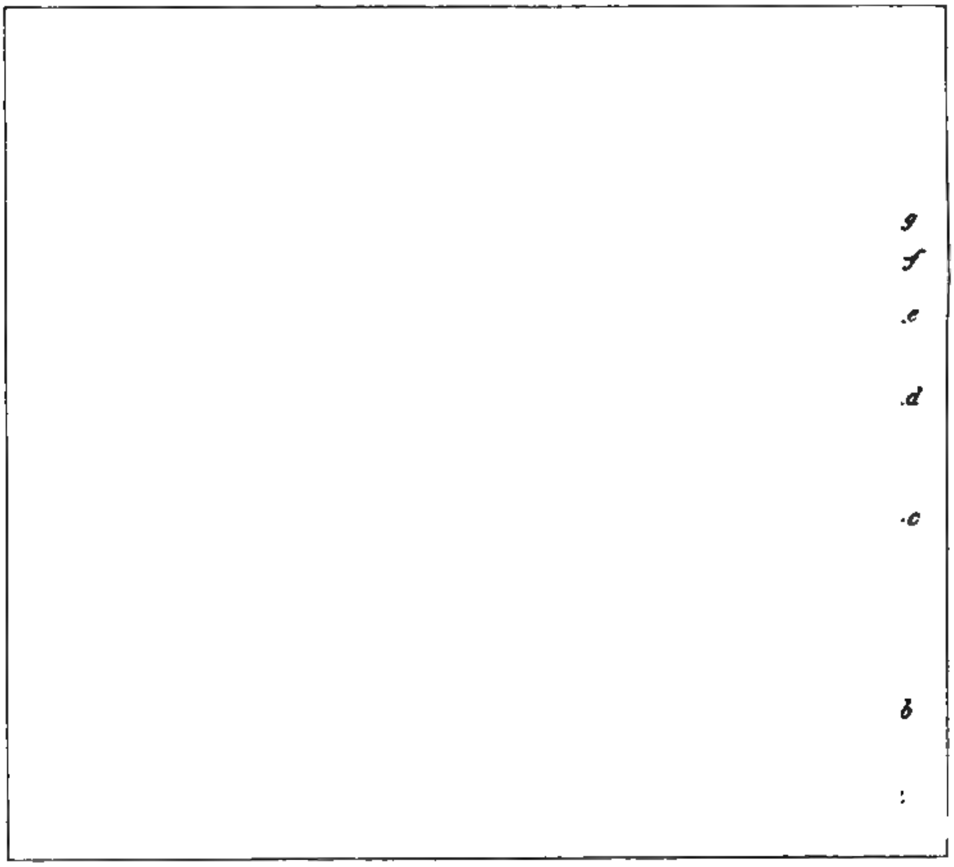

Fig. 132. Overgrowing frost split in apple branch, produced by artificial cold.

a. Canker of the Apple Tree.

The canker of the apple tree occurs in two forms, of which the more common one is distinguished by a broad, central exposed wood surface formed from the open, protruding, blackened wood body and is surrounded by roll-like, strong calluses, developing outwardly each year like terraces. At the centre of the wound is found frequently the remainder of a small stump of a branch. This is indicated in Fig.. 133 by *z*, while the nearest overgrowth edge is indicated by *u'*. We see how the wound surface gradually increases since the first formed, still rather flat edge dies and turns

black, while that of the next year (u'') develops in the form of terraces. The process is repeated from year to year (see u'''-u'''') until nearly the whole extent of the axis has been attacked by the canker excrescence and dies. Such places, with open wounded surfaces which become wider and wider, are called "*open canker.*"

The increase in thickness of the overgrowth edges toward the outside is explained by the fact that plastic material, coming from above, from still living, leaved twigs, has to be divided in each successive year over a smaller part of the twig or trunk surface because of the retrogression of the overgrowth edges and accordingly provides relatively more abundant food

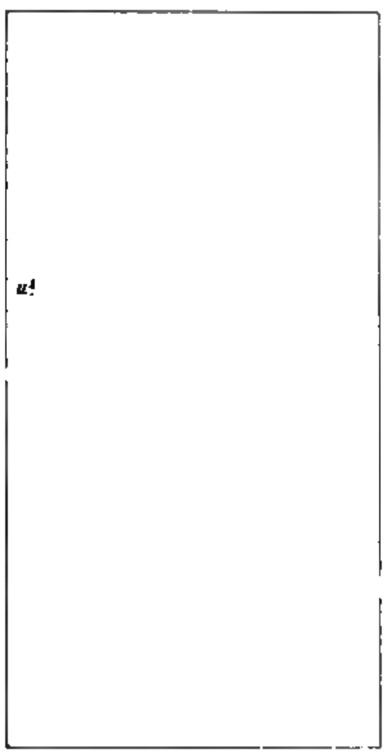

Fig. 133. Open apple canker.

Fig. 134. Closed apple canker.

substances for the formation of new parts, in the cambial zone, which is growing shorter and shorter.

The closed canker (Fig. 134) when completely developed, represents approximately a spherical wood excrescence (u) at times exceeding the diameter 3 or 4 times, knotted and usually completely covered with bark. This wood excrescence is flattened at its tip and deepened in the centre of the upper surface like a funnel (t). In contrast to open canker, this swelling covers a much smaller part of the axis bearing it but makes up for its lesser extent in width by a considerably greater radial elevation, i. e., greater height.

Blight may often be proved also on the branches and twigs on which occur canker excrescences. In all three varieties of injury a bright red to brown, flat conical, or oval fruit body of *Nectria ditissima* may be found, not infrequently, in winter on the dead, cracked edges of the wound.

If a cross-section is made through the excrescence of a closed canker, approximately the following picture is found.

We see (Fig. 135) the whole large swelling divided radially into two groups by the split (*sp*) with its roll-like edges. This cleft forms the inner continuation of the outwardly recognizable funnel-like depression on the flattened top of the canker excrescence (Figs. 134, 135 *t*). At the bottom

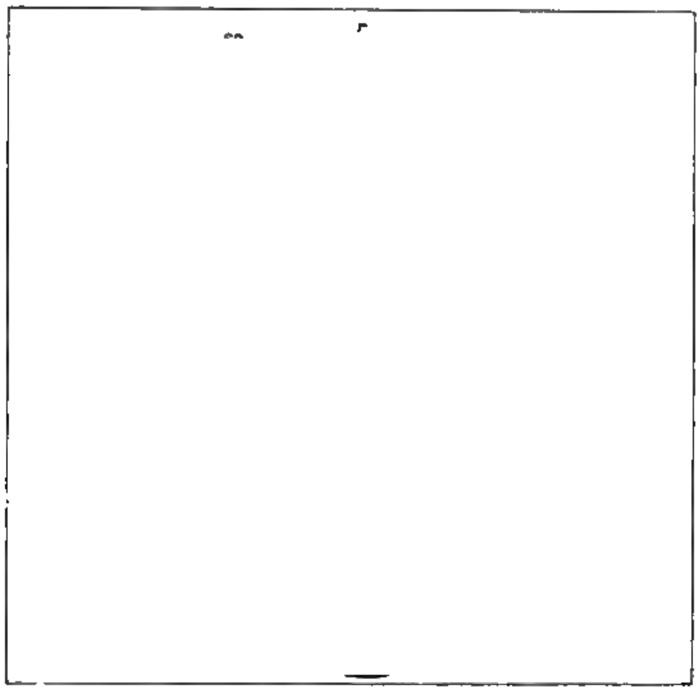

Fig. 135. Cross-section through an apple branch with a knot of "closed canker."

of the cleft usually lies a brown, mealy, or putty-like mass which is found to consist of humified cell remnants. The edges (*r*) of the cleft are also strongly browned. They are formed by thick-walled, parenchymatous-like porous cells, provided with a dead, brown content. The further back one goes from the edges of the cleft, or the point of dying, toward the healthy tissue of the trunk, the less noticeable is the brown color. The tissue becomes white and is formed of parenchymatous wood which contains an unusual amount of starch. Groups of strongly refractive cells gradually appear in these masses of parenchyma wood. They are clearly elongated, thick-walled wood cells which, isolated at times, or in small groups, appear irregularly distributed in the parenchymatous wood. (Fig. 135 *h*). Com-

pare the cross-section given in Fig. 132, due to an artificially produced frost split on the branch of an apple tree. Parallel with the appearance of the first wood cells is that of the hard bast cells (Fig. 132 *h b*) in the bark. These prosenchymatous elements in the edge of the wound, formed of parenchymatous wood, are the initial stages of the normal annual ring formation and extend from the edge of the wound backward, approaching one another more and more closely, until they have united in a normal annual ring on the healthy side. If we start with the normal annual ring zone on the healthy side of the trunk, we may thus conceive this formation as follows; it is as if the prosenchymatous tissue of a healthy annual ring (Fig. 135 *c h*) had been divided into several radiating branches (Fig. 135 *h*) within the canker excrescence which chiefly consists of parenchyma wood, rich in starch and containing here and there large crystals of calcium oxalate. (*Radial division of the annual ring.*)

The edges of the wound, themselves, are not found united; the cleft, therefore, in spite of its narrowness, has never completely coalesced since the outermost cells, edging the cleft, constantly die.

In proportion to the uncommonly luxuriant new formation, the number of dying cells in "closed canker" is very small. The dead place here always forms only a narrow twisted cleft; while in "open canker" the originally dead tissue represents a broad surface and the dying back of the edges of the wound extends so far that not only the wood surface which first remains uncovered, but also each overgrowth edge is incompletely covered by the succeeding one.

The characteristic radial division, or splitting of an annual ring (Fig. 135 *nh, h*) within the woody, parenchymatous edges of the excrescence is less conspicuous in open canker and may completely disappear in case the entire trunk, which has remained healthy, participates, at the height of the canker-wound, in the exorbitant thickening, i. e., excludes a one-sided hypertrophy of the trunk.

The determination of the dry substances in normal and cankerous wood in the cherry gives a proof of the softness of the tissue in the canker excrescence. Normal wood has 66.9 per cent. of dry substances; the overlying canker wood, only 45.1 per cent.

From the fact that the canker excrescence frequently exceeds considerably the thickness of the two or three year old branch which bears it, we may conclude that the excrescence which is never found on the green shoot of the current year, i. e., begins only in the woody twig, must grow very rapidly. With such rapid development of the tissue, it is not surprising that the fluctuations between cloudy, wet weather and periods of drought can so manifest themselves that, within one summer, alternate zones of thin-walled and thick-walled wood are produced in the canker excrescence. This is found if the darker zone, extending from the pith (*m*) in Fig. 135, is traced further. It corresponds to the thick-walled wood elements and, in the normal part of the trunk, indicates the autumn wood in contrast to

the more abundant spring wood but always within the canker excrescence prosenchyma wood in contrast to parenchyma wood. The illustration shows the last formed, dark rings in the healthy part divided radially toward the diseased part. *n* indicates a diagonally cut, dead branch.

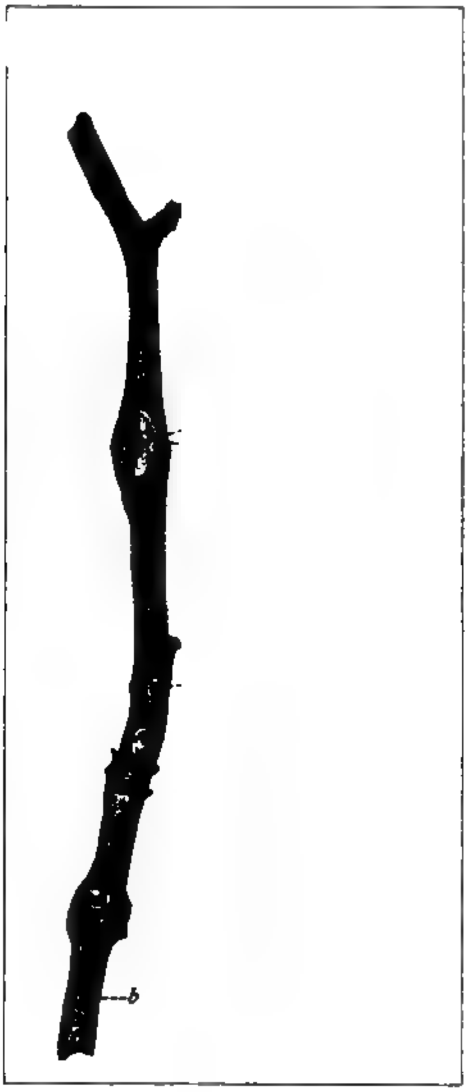

Fig. 136. Juvenile condition of apple canker.

This luxuriance of growth, which manifests itself by the formation of the radiating canker excrescence, may not, however, lead universally to the conclusion that the growth of the tree as a whole is always luxuriant. On the contrary, a regular occurrence of canker knots is found in weak, slender trees in certain localities.

Cankered and also blighted trees usually show a very luxuriant lichen growth. At the central place of attachment of such lichen cushions it may often be proved that the cork layers of the branch have been separated and the thallus cords shoved in between them. In fact I could observe cases in which the lichen thallus penetrated the whole protective cork layer of the branch and reached the collenchymatous bark cells, some of which still contained chlorophyll. The lichen growth may, therefore, not be as injurious as the yellow and green forms are generally declared to be. How much, however, the spread of the lichen depends upon some individual peculiarity of the tree is still unknown to us (probably a greater tenderness porosity and torn condition of the bark), as is explained by an observation on grafted older trunks of Fraxinus. The stock, possibly one to one and a half meters tall, appeared only scantily covered with lichens while the grafted scion, which at times bore a 12 to 15 year old crown, was closely covered by lichen growth. As a rule, cankered places on old ash trees, standing on wet ground, are covered with lichen.

In regard to the juvenile condition of cankered places, I mentioned under Frost Tears that I considered such small tears to be the initial stages of the canker excrescences. In the adjacent picture I give an illustration of two branches in natural size, as I found them on an apple tree, suffering from canker. In Fig. 136 *a* is shown an oval depressed part of the bark near a bud. The growth which took place after the injury has so increased the tension at the dead spot that the dry bark at its centre has split. At *b* we see a somewhat further advanced stage. The dead bark in the middle of the wound has already been raised by the overgrowth edges, appearing at the side and united with one another. The places indicated at *c* and *c'* in Fig. 136 show conspicuous, protruding knots, with a uniform new bark covering. At *r* are the dried scaley, somewhat distended edges of the primary bark of the branch, which has been ruptured by frost. In this, the places are not near a bud; *c* is in the middle of an internode and *c'* on the side opposite the bud. In Fig. 136 *d* the wound has attacked the tissue surrounding a bud. The bud is dead and the region depressed.

The wound surface is here very great, the bark *r'*, under which air has penetrated, is still connected with its healthy surroundings and that newly produced on the edge of the dead spot has caused a widening of the branch, as is very frequent in blight wounds.

Reproductions of open canker of the apple tree, as well as closed canker, show that the region of the trunk, bearing buds or young sprouts, is preferred in the formation of canker. Such a preference of the region below a short twig is shown in the adjacent figure of a small pear branch (Fig. 137). Directly underneath the short twig at *a* we find a deep, already overgrown frost tear. At *b*, the region of the shortened branch ring with its short internodes and many weak buds, the bark has been split by many small tears and dried like scales. The young, upper part (*c*) of the branch has remained healthy. In such bark splits frequently the strongest overgrowth edges are found which often represent a single enclosed knot covered with uniform bark, but having often two lip-like excrescences touching one another and usually running longitudinally. Such wound edges at times appear folded toward the twisted central cleft, the original bark tear, from there falling away; they then resemble the canker wounds. The bark tears do not always represent longitudinal clefts and, accordingly, the overgrowth does not always occur in the form of two protruding lips but rather as knotty, spherical elevations with a crater-like central depression. On a branch 9 mm. thick, I found canker knots 13 mm. high and 35 to 45 mm. broad. Other branches, just as

Fig. 137. Preference shown by frost for the base of the branch.

thick and two years old, at times showed only very weakly callused, uniformly closed protuberances, covered with new bark, which break out from the cleft in the old bark.

The studies here cited determine that each canker spot has, as its initial stage, a wound which extends as a narrow radial tear into the cambium and kills it slightly back from both sides. This wound must be produced shortly before, or at the time when the trunk of the tree develops the greatest growth activity, since the wound surface will attempt at once to form a covering by means of very luxuriant overgrowth edges. The luxuriance of these overgrowth rolls manifests itself in the fact that, especially in the closed form of canker, a partition of the annual ring usually occurs, the edges of which chiefly consist of parenchyma wood. The edges of the wound are very susceptible because of this porous structure, so that they succumb with ease to injurious attacks.

We must consider frost as the cause of these forms of disease because it has been possible to produce, by the action of artificial frost, the same initial stages as are found in canker wounds.

However, a number of very reliable observers have determined that it is possible by the injection of a (capsule) fungus, *Nectria ditissima*[1], to produce wounds, the forms of which resemble perfectly those of the open canker of the apple. I can confirm these statements by my own experiments. One has indeed a right to speak of a fungous canker but the above named parasite *is not able to attack an uninjured axis.* It can spread destructively only if it gets into a bark wound. All inoculation experiments agree in this. On the other hand, the same Nectria is found in apple trees, beeches and other varieties of deciduous trees without causing any canker excrescences whatever. Therefore, it cannot be termed the specific incitor of canker excrescences but will give rise to these only occasionally when very definite secondary conditions co-operate simultaneously. Besides the presence of a fresh wound surface, it depends also upon the specific peculiarity of the tree, i. e., the cultural variety, which must possess the ability to respond to the wound stimulus with quickly developing, very luxuriant overgrowth.

This ability is so typical that in general practice one speaks of "Varieties with a canker tendency." Besides this, experience has shown that the tree easily becomes cankered in certain places and kinds of soil. These are the so-called frost holes, having a marshy soil consistency, an impervious sub-soil, etc.

These are well-established facts. If we now keep in view the fact that *Nectria ditissima* must have some wound for infection, we must ask whence came these wounds. From observations made in nature and from the results of experiments with artificial frost, we are convinced of necessity that frost injuries are the most easily accessible. Paparozzi holds to

1 See literature in the second volume of this manual, p. 209.

the same standpoint for the canker of pear trees[1]. If the frost wounds are flat surfaces such as will be found later under "Blight," the Nectria will infest the tree without its formation of luxuriant overgrowth edges. If, however, narrow frost tears, extending into the cambium, are produced into which the Nectria find entrance, the tree responds with the formation of canker excrescences in case climate, habitat or specific characteristics make it capable of so doing.

Accordingly, the fungous canker also appears to be essentially dependent upon frost injury and its combatting or avoidance will have to be carried on with due consideration of the danger from frost.

b. Crotch Canker in Fruit and Forest Trees.

"Crotch canker," which is of frequent occurrence in forest and fruit trees, should be mentioned as an especial form. It consists of frost wounds found at the bases of the branches, or twigs, which belong to the group of open cankers and are formed from black, dead surfaces differing in size with luxuriant, irregular overgrowth edges. The angle where the branch joins the main trunk is separately attacked in many varieties. In the so-called *"bifurcations,"* or forkings, where the difference between the main and the lateral branch disappears so that two equally strong branches grow out from one point, the exposed and blackened place in the wood is usually elevated at both sides and, accordingly, the overgrowth edge is formed from the material of both branches (cf. Fig. 138). Aside from the more sensitive, imported trees, our indigenous forest trees, according to Nördlinger[2], are also exposed to injuries at the crotch, especially when young; thus, for example, beeches in shady positions and on poor soil, in which the internodes at some distance from the crotches are also often covered with frosted surfaces. The annual growth of the oak also suffers on poor soils and the ash is found to be injured if the tree stands in depressions with a heavy clay soil. In such damp places I found the overgrowth unusually luxuriant but so covered with thick, split bark, overgrown with lichens, that it had become irrecognizable.

Fig. 138. Crotch canker.

Opposed to the theory, which Hartig represents, that crotch canker is conditioned by spring frosts, Nördlinger thinks the cause is frost at the beginning of winter. He bases his opinion on the investigation of the wood ring and on the fact that, in thousands of cases, crotch canker is very

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[1] Paparozzi, G., Il cancro del pero. Roma, Offizina poligrafica; cit. Bot. Centralbl. 1904, v. XXVIII, p. 94.

[2] Die Septemberfröste 1877 und der Astwurzelschaden (Astwurzelkrebs) an Bäumen. Centralbl. f. das ges. Forstwesen. Wien 1878, Part 10.

abundant high up in the crown and in shady places, i. e., those less exposed to spring frosts.

The especial susceptibility to frost of the base of the branch is explained by the fact that, on account of the greater number of buds originally set there, more parenchymatous medullary bridges are present, which traverse the wood ring. The parenchymatous wood is more tender and contains more starch. To this should also be ascribed the fact that bark beetles like to settle in the crotches and that wood mice, as Nördlinger states, frequently eat only the base of the lateral branches in poplar suckers (*Populus monilifera*). Therefore the frost, i. e., the spring frost, kills the base of the branch most easily.

In old, weakly growing trunks, the luxuriance of the overgrowth edges decreases considerably and can become so slight that only narrow, circular overgrowth edges are present, which push out slowly from under the dead bark. This blight corresponds to that of the crotch injury, since in open canker, the first stage is not a cleft but a collapsing, drying dead bark surface. Hence, the expression *"crotch blight"* frequently used by many practical workers.

c. Canker on Cherry Trees.

In sweet cherries are usually found semi-cylindrical protuberances on the twigs, or older branches. The outside of these swellings, often thicker than one's fist, not infrequently seem depressed, as in blight; the dead bark is split and partially stripped from the blackened wood body, still remaining attached as larger scales with up-rolled edges (cf. Fig. 139).

The barrel-shaped swelling on the branch represents an abnormal development of the overgrowth edges (*u* and *u'*) of the wound (*sp*) which does not close entirely, as is also found in the "closed canker of the apple." In the latter, however, the overgrowth tissue is a sudden, unusually luxuriant widening of the annual ring, while, in the cherry, the swelling of the normal side of the twig shows a gradual transition to the excrescent overgrowth edge. On this account, the closed canker of the apple has the form of knots but the completely developed canker of the cherry a gradually increasing barrel-shaped thickening. Besides this typical form, various transitions are found from the closed canker knots, on the one hand, to the flat wound, on the other, which is termed blight.

Conical swellings are found at the base of older branches of trees, suffering from canker, which can offer all the transitional forms up to the typical canker swelling. The initial stages are found on one side of the branch in the form of a small frost wound alongside the first annual ring. An especial emphasis should be laid here on the fact that the enormous overgrowth tissue seems often to be developed from a medullary bridge. This, therefore, points to some direct injury to the bud. The development of the overgrowth edges is continued in subsequent years, when only paren-

chyma wood is formed in which starch is rapidly and abundantly deposited. If the canker swelling has become considerably extensive, the branch dies, as a rule, above this swelling; in this, stroma-forming fungi (usually from the family of the Valseae) greatly co-operate. They appear in the form of small warts.

If the young branches (1 to 2 years old) of trees suffering from canker are examined, blight-like places, often several centimeters long, are found, with lip-like overgrowths instead of individual buds, while, on the parts of the branch above and below these places, the buds have developed to short shoots. It is evident from this that the injury to the branch must take place before the breaking of the bud.

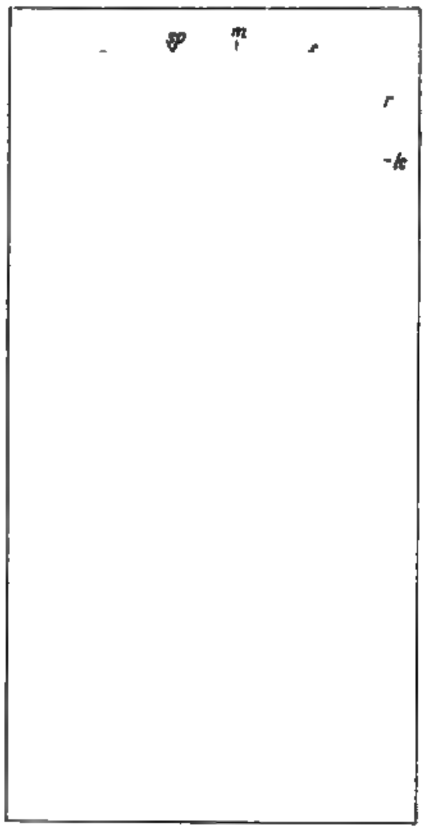

Fig. 139. Cherry canker frost cleft with overgrowth edges in longitudinal view and cross-section.

Since, however, no injury of any kind can be ascertained in the year in which the branch is formed, but will be found only in the following spring, it must have arisen in the winter or at the beginning of spring; the assumption is, therefore, pertinent that the bud, as it unfolds in sprouting, is killed by the frost and that the accumulated plastic material is now used in the formation of the excrescent edges of the wound. Since the tissue of these overgrowth edges remains as soft as the parenchyma and is almost always found filled with starch, it is clear that, in the following winter, its edges succumb very easily to injury from frost and new excrescences are produced from the deeper lying zones which remain healthy. A consideration of the cross-section in Fig. 139 makes clear the whole process. This shows that the clefting of the axis has begun at a short distance from the pith body (*m*) and in the second annual ring. The third annual ring has already furnished luxuriant overgrowth edges (*f*) which, in turn, split the following year (*sp'*). These secondary clefts cause secondary overgrowth (*f'*). The barrel-shaped canker swelling, however, is formed chiefly by the excrescent wound edges of the main cleft, which are radiatingly arranged (*k*). Thus an annual ring inside the canker swelling is divided into several rings, as in the closed canker of the apple. The bark body

(*r*) also forms corresponding excrescences and, in places, develops thick bark scales.

In the canker of the cherry, as in all canker diseases, only scattered individuals are found diseased in large plantations. I often found in the healthy shoots of these cankered examples abnormally broadened medullary rays, a phenomenon which may be observed also in other kinds of trees. I, therefore, surmise that the *inclination to become diseased with canker may be found in the individual tendency toward a widening of the medullary rays.*

The Canker (Scab) of the Grapevine.

In the older wood of grapevines near the surface of the soil, about 10 to 50 cm. above it, are found scattered, small spherical or large barrel-shaped, out-pushings of the wood from the bark, with a beady, irregular upper surface, split lengthwise into fibres. Fig. 140 shows a beady canker swelling between the strips of bark which are drawn in white. In small, isolated outgrowths, their production, according to Göthe's[1] investigations, is clearly recognizable as the overgrowth tissue of longitudinal clefts. The clefts appear at the edge of the annual ring, from which it must be concluded that they were produced at the time when the development of the next annual ring began. caused by the dying back in spots in the cambial zone in the spring. In regard to the production of the excrescences, I have stated some differing observations of my own, under the head of the disease to be treated next,—Canker of the Spirea.

Fig. 140. Canker excrescences in the grapevine.

The injury, which killed the cambium, has also caused a *considerable circular surface* on the old wood to turn a deep brown. The overgrowth beginning at the healthy place, which often quickly closes the cleft, is characterized by an excrescent luxuriance of the wood and bark. The woody edges, curling out towards one another, consist of soft, ductless parenchyma wood, without any real

[1] Mitteilungen über den schwarzen Brenner und den Grind der Reben. Berlin und Leipzig, H. Voigt, 1878, p. 28 ff.

prosenchymatous elements, i. e., they exhibit the characteristic structure of the excrescent wound wood. If the overgrowth edges have united into a connected annual ring, this grows further in such a way that it is subdivided by medullary rays. The direction of these medullary rays continues that of the medullary rays of the wood formed the previous year. Therefore, this wood has undergone only a temporary interruption in the brown dead tissue.

The changes and tissue excrescences described are never found in wood of the current year.

Göthe thinks the bead-like appearance of the tissue excrescence, which, growing extensively radially, splits the old bark, is explained by a complete "overlapping, inward growth" of the overgrowth rolls, which are present most abundantly at places on the vine lying about 30 cm. above the surface of the soil. Examination shows that, starting at such places, the number and extent of these swellings decrease away from as well as towards the soil; close to it, and about one meter away from it, they occur very rarely. With a slight development of the disease, the attacked trunks may vegetate for several years and then still produce bearing wood. With a greater development of the canker swelling, the wood, lying above it, dies.

The rapidity, with which the canker swelling is produced, is proved by the fact that, on August 8th, plants were found in which the grafting tape lay embedded 0.75 cm. in the tissue excrescences. Therefore, the entire canker swelling, 2.5 cm. thick, can only have been produced after the time of grafting (in May), for it can not be assumed that a scion would have been inserted in a diseased vine.

Göthe has proved by the following experiment that the injuries to the cambial ring take place in the spring. In April, when the vines were pruned, 12 strong bearing vines were tapped, between two nodes, with a dull iron, in such a way that an injury to the cambial layer could be assumed. Glass tubes were then shoved over the injured places and the openings closed. The first traces of the swellings could be proved as early as June 8th, while on specifically scabby vines the tissue excrescences did not appear until June 20th. Up to autumn, perfectly normal scab structures continued to form in the glass tubes, with also the same anatomical structure as naturally formed excrescence edges.

Spring frost may be considered as the cause of these excrescences in nature. Most of the literature which proves the appearance of grape canker after spring frosts also favors this assumption[1]. It is also strengthened by the discovery that grape canker occurs only in the so-called frost holes. Göthe cites in this connection, an example from a vineyard which began on a small slope, passed through a hollow and rose again on the opposite slope. On both slopes the plants were healthy, but in the hollow were found to have been attacked by the disease. In a subsequent test, the

[1] Göthe cites v. Babo, Weinbau, p. 305; Dornfeld, Weinbauschule, p. 129, Köhler, Der Weinstock und der Wein, p. 205; du Breuil, Les Vignobles.

observer found that the disease had occurred on 20 other vines, which stood in depressions in the soil.

The fact that the grape canker appears at a definite height on the vine is explained by the various differences between the heat maximum and minimum to which the vines, at different heights, are often exposed at the time of spring frosts.

Draining of the soil might prove the most effective method. Köhler has already announced favorable results in his above-mentioned works. Besides this, attention should be given to the planting of hardier varieties and especially the choice of suitable positions (moderately moist, porous and warm soil).

It is not inconceivable that the scab, without the action of frost, may be produced by an accumulation of plastic materials, as Blankenhorn and Mühlhäuser believe they have observed as the result of too severe cutting back[1]. It is certain that the beginnings of the swellings, occurring in the form of medullary ray excrescences, can appear in the vines in which in the spring the bark has been raised in places from the wood of the previous year. Such canker excrescences, as said above, can mature without any injury from frost, just as canker-like, excrescent overgrowth edges are found in luxuriantly growing pomaceous varieties. But in such cases, the deep, extensive browning of the wood body is lacking.

c. Canker on Spiraea.

A disease, not yet described, showing great relation to the canker of the grape, attacks the bases of the stem of *Spiraea opulifolia.* The disease seems to occur more commonly only in regions with very cold winters. The material which I had for observation came from East Prussia.

Other wood, at least two years old, with strong annual rings shows at the stem bases unusually abundant hemispherical swellings of the wood, scattered, or in rows like chains of beads, or in masses. (Fig. 141 *A, k, kk*). The size of these swellings varies from a few millimetres up to 1.5 to 2 cm. in diameter. The swellings are brown, darker than the outermost bark layers, which they rupture, and loosened in tatters. They are often cleft or depressed in the centre like a funnel and provided with thick granulated, torn surfaces. No single bark layer can be raised, since the tissue of the swelling is brittle and easily breaks off in pieces.

In cutting away a considerable swelling, or, as one is justified in saying, canker knot, it is found that lamellae or firmer material radiate out from a more or less broad base. However, the lamellae neither extend through the whole thickness of the canker, nor are they separated sharply from the tinder-like, decayed, darker ground tissue. This itself is to be considered an excrescent *continuation of the last annual ring,* which becomes more and more delicate toward the periphery.

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[1] cf. Würzburger Weinbaukongress.

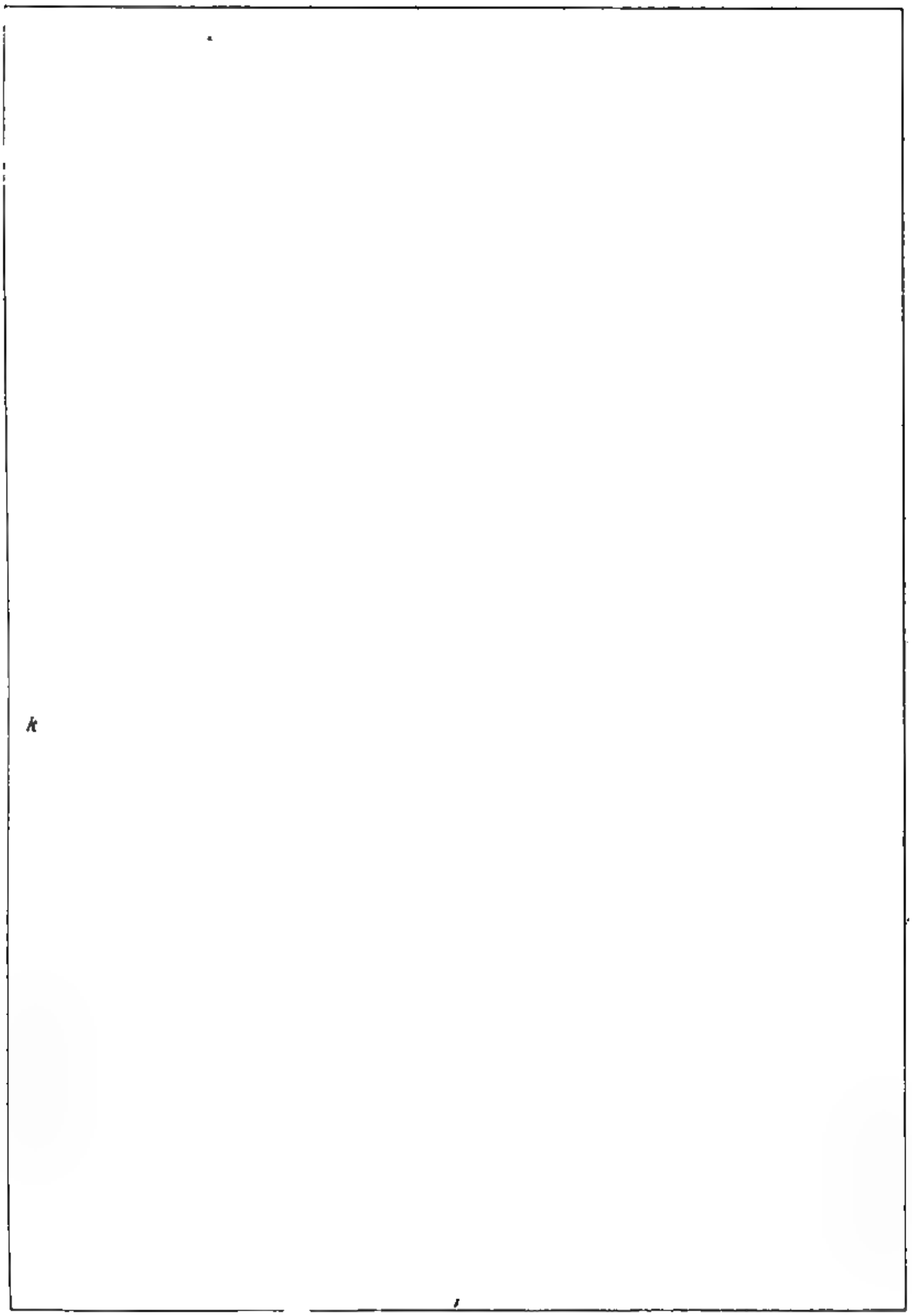

Fig. 141. Canker on Spiraea.

In Fig. 141 *B*, which gives a cross-section of the canker knot (*k*) from Fig. 141 *A*, *m* indicates the pith body; *a*, the uninjured annual ring of the first year's growth; *b*, the cleft ring of the second year; *c*, the wood of the third year, which is growing out into the canker swelling (*k*); *i* represents the firmer tissue islands and stripes in the tinder-like ground tissue.

In the cases which have been observed up to the present, the main part of the canker knot has seemed to be the production of a single year and, in fact, a one-sided woody excrescence over a place which, even in the previous year, had formed a wedge-shaped zone of porous, parenchymatous wood tissue, its pointed end toward the interior. In so far two years are necessary for the completion of the canker knot. If the above mentioned, wedge-shaped zone is traced backward to the annual ring of the previous year, it will be seen that this originates in a brown, slender place in the first spring wood.

The adjoining anatomical picture, Fig. 141 *C*, will facilitate the explanation. The whole figure *C* is a radial section of the second annual ring from a Spirea stem and contains the tissue zone which is preparing to develop into the real canker swelling. The line *f* to *ff* represents the strip of changed tissue, which in its further development in the following year, will have become a complete canker knot. The tissue shown at *a* is the autumn wood of the first annual ring. No disturbance has been observed in the wood body of this first annual ring, just, as in the canker of the grape, the first annual ring has a perfectly normal structure. The wood of the second annual ring (*b*) at first began a normal development and continued it up to *b'*.

At this time occurred some disturbance which produced the cleft (*d*), and browned its edges (*c'*). The time this split was produced must have been that of the greatest formation of new wood for, only a few cell rows farther, we find that the split is closed at *h*, and the annual ring has grown further with the formation of groups of normal parenchymatous elements (*p*). Only a single cell-row (*k*) forms a radial stripe, with shorter cells containing wider lumina. Now the abnormal wood stripe, instead of disappearing as the annual ring matures and increases in width, grows broader, since more and more cells take part in the changed form of construction (*kk*). Thus the disturbance advances until the second annual ring is finished and then begins, to a renewed extent, in the spring zone of the third annual ring (*c-c*).

Even when the second annual ring is finished, the stripes of the beginnings of the canker may be seen to project as slight elevations above the periphery of the remaining wood ring. In the spring of the third year the new formation at this place is so luxuriant that the rapidly growing canker knot, strengthened by the equally rapidly excrescent part of the bark (*k l*), ruptures the normal bark (*r*) at *sp* and now grows further, as it were, as a foreign structure, in order, after some weeks, to end its growth, being a complete canker knot 1 to 2 cm. thick.

Similar formations are found in the *canker of the grape*. Only I have found as yet that the disturbance, setting in at the beginning of the second year, and corresponding to the holes (*d*), consists of a broader tangential elevation, circular in form. It give the impression that, at the beginning of the period of growth, the bark was raised from the wood body for a considerable distance. My repeated experiments with artificial frost show that this process can actually occur and, in fact, it is met with rather frequently in various trees. As a result of this lifting of the bark, a tangential hole is produced on the grapevine, usually at the place where, on Spirea, the slender, radial cleft is found. The raised bark forms, first of all, wood parenchyma and this soft wood body passes over very gradually, in the course of the following summer, into normal wood. Here, however, some of the broad medullary rays are found above the raised part which have developed especially and at the end of the year project as delicate tissue caps.

In the grapevine, as in Spirea in canker formation, these are not necessarily overgrowth edges, as is always the case in the canker of the apple; in the former, tissue cushions of a wood body which has become parenchymatous develop to canker knots. These cushions at first appear uninjured and are *at any rate caused by some previous disturbance*. This explains the theory expressed by Blankenhorn, on the canker of the grapevine, viz., that the stoppage of plastic materials (for example, with too strong pruning), can cause the canker excrescence.

The formation of the canker excrescence often indicates some modification, inasmuch as the canker cushions, produced in the first year, are partially killed by the frost. Then the central, most delicate part suffers and represents a black, dried core. In the following spring only the edges grow further, just as do overgrowth edges, and line the cleft, as is shown in Fig. 141 *B*. It has been said that the parts of the edges of the growing canker knot continue growing "after the manner" of overgrowth edges. Actual overgrowth edges, spirally curved, are found only rarely (as in the canker of the grape).

Fig. 141 *B* shows that the wood ring of the third year passes over imperceptibly into the canker swellings. Therefore, the canker swelling is actually a wood formation but this wood, because of the enormous rapidity of the tissue formation, is a structure so soft and so similar to the likewise excrescent bark tissue, which is dying back from the outer side, that it is often difficult to determine the boundary between them. This porous wood, which I have found so very soft only in the canker of the rose, forms, on the dead swelling, the brown,, tinder-like ground mass, of which we spoke at the beginning. The firmer, lighter colored parts are the islands of thick-walled wood cells and ducts (Fig. 141 *B, i*) increasing in breadth and thickness at the periphery. In canker knots of different sizes, the groups of ducts (*i*) are sometimes found in the form of wedge-like lamellae, becoming thicker toward the outside, sometimes (as in Fig. 141*B*)

in the form of spherical groups with a sheath-like arrangement of their elements. The groups not infrequently unite and in this way cause a greater firmness but no complete wood ring has ever been observed. It is these isolated parenchyma and duct groups which in pruning so greatly resist the knife, that they are torn loose from their connection with the other tissue before being cut through. Hence the easy crumbling of the canker knot.

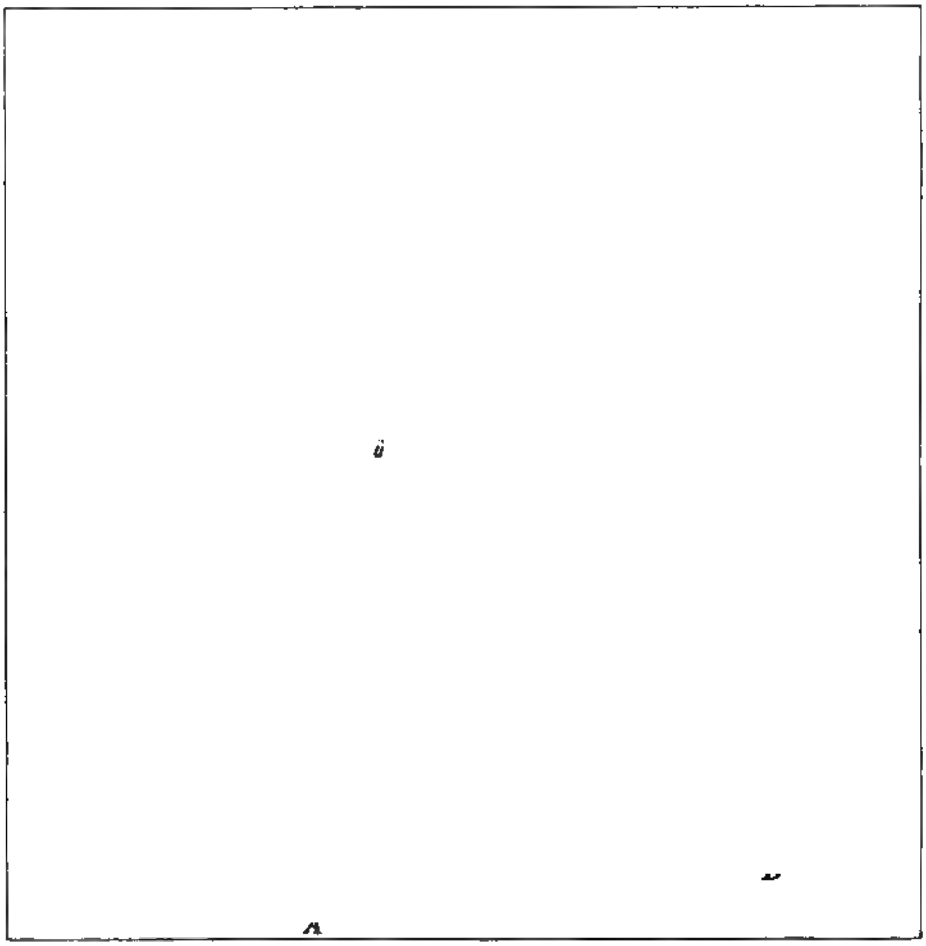

Fig. 142. Rose Canker. Concentric overgrowth edges may be recognized, rising like terraces around a central, dead wood surface.

f. Canker of the Rose.

In the culture of the newer climbing roses, which (according to Crépin-Brüssel) have resulted from a crossing of *Rosa Indica* with *R. multiflora* and are called Polyanthus varieties, we have become acquainted with a phenomenon which comes under the head of canker excrescences. The adjoining Fig. 142 *A* and *B*, represents such canker swellings as are

found at the base of the strong stems of *Crimson Ramblers* in Germany. Their appearance on the lower part of these rose stems, which, as is well known, grow most luxuriantly in Germany, reminds one of the same occurrence in the canker of the grapevine. As in all forms of canker, we find here also that the region of the axis is preferred where branches (*A*, *a*) are produced and the base has strongly thickened or split open into curled excrescences (*B*, *üb*). As an explanation of this phenomenon, it need only be remembered that the wood ring is broken and especially susceptible to disturbances at that part of the normal axis where a branch starts. for the pith body is widened at the place of insertion of the twig into a pith bridge, transecting the wood ring and passing over into the lateral branch. In such a developing branch the eyes stand closest together at the base; they may often be but little developed, because the leaves are still bract-like or incomplete, but the parenchymatous medullary bridges, which traverse the wood ring, are present.

The canker spot on the main axis in the present case, as in the "open canker of the apple," shows a central wound surface with an exposed brown wood body (Fig. 142 *A* and *B*, *w*). This surface is encircled by terrace-like, rounded overgrowth edges (*ü*). These wound edges, however, do not retain their uniform wall-like character, as in the canker of the apple, but develop into irregularly knobbed, or beaded, heaped up tissue masses. In other cases, the canker of the rose occurs, like the canker knot in Spiraea, in boil-like, united and elongated wound edges, which line a long cleft, starting from the base of the branch. All excrescent tissues ultimately rupture the bark (*r*).

An insight into the production of these excrescences, which are not exceeded in luxuriance by any other canker swelling, is obtained from the above reproduced cross-section of a rose stem, at the place where it has formed a small, isolated bead-like elevation (cf. Fig. 143). We perceive that the stem has developed normally in the first year; a normal wood ring (*h*) surrounds the pith body which has broad medullary rays (*mst*) and which ruptures later (*v*). In the second year, as the first cell rows (*gr*) of the new wood ring were in the midst of developing, some disturbance must have made itself felt in the form of some break in the tissue, for the new wood ring (*hp*), for the most part, has taken on the character of the parenchyma wood and only in places (*h'*) has it retained the normal wood structure, characterized by the formation of ducts and thick-walled wood cells. The cause of this breaking up of the tissue has been a split in the bark, traces of which may be seen in the lip-like, small indentation at the upper side of the figure. The cork layers (*k*) of the bark, which cover this, have been split and the overgrowth tissue (*w*) swelling out from both sides, which has been covered in turn with a cork mantel, has coalesced into a closed mass in the immediate proximity of the tear (which is not shown in the drawing). If this tissue is traced backward toward the healthy (upper) side of the branch, starting from the most luxuriant place of

excrescent tissue (w), it is found that this gradually dwindles away and inside the bark begins to take on a normal character (fg.) Here the arrangement of the hard bast cords is still approximately normal but their structure has been changed greatly. The majority of the bast cells have a yellow, swollen content and easily browned walls. Nevertheless, they are distinguished, as strong, light-colored groups from the deep brown bark

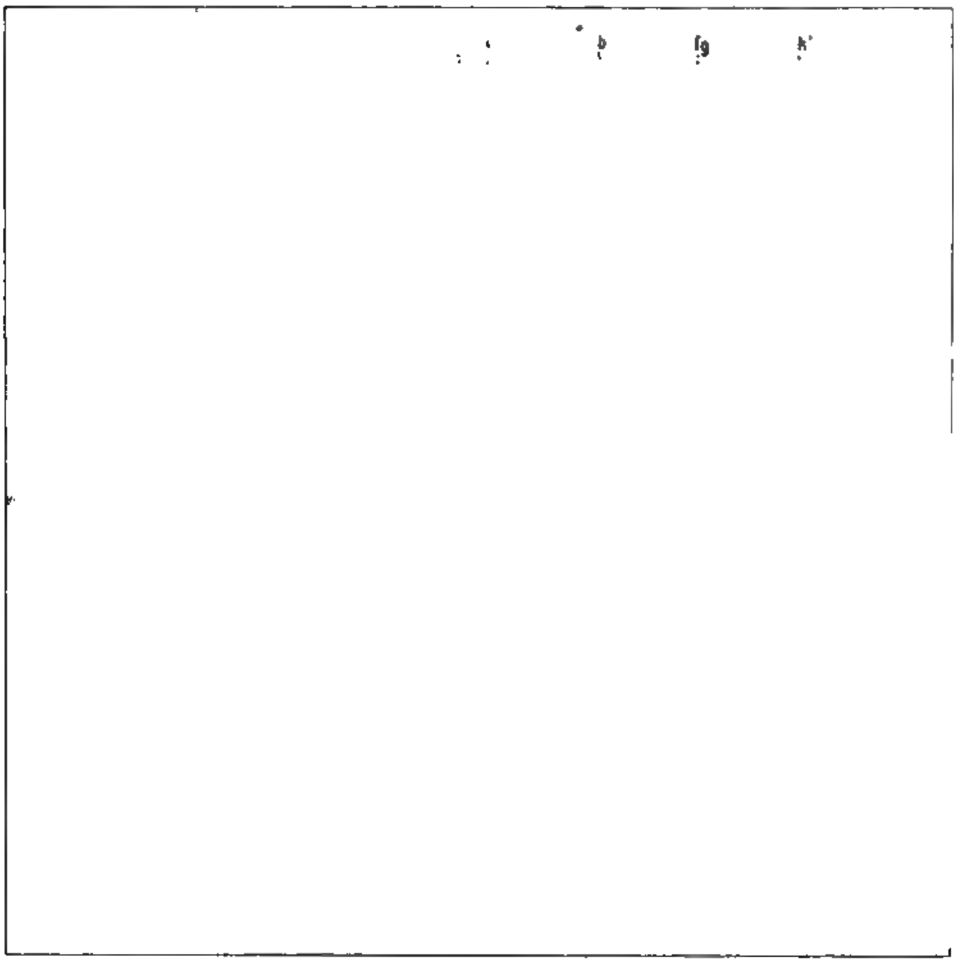

Fig 143 First stages of the rose canker.

parenchyma which is cut off from the outer collenchymatous bark layers by the subsequently produced layer of plate cork (k').

The drawing shows, however, that the ring of bast cells (b) is removed farther from the wood body the further it advances into the tissue of the excrescence. It is, therefore, pressed away from the wood body by the increase of this body. At the same time the bast ring is seen to have been

pushed back further from the outer collenchymatous layers. Therefore, cell increase must have taken place in the primary bark.

The question should now be asked as to whether the tissue, which presses the bast ring away from the wood, is exclusively a product of the secondary bark or whether the wood cylinder itself has contributed to this. We find the answer in the tissue group (*hp'*) which represents the parenchyma wood. We find such groups of parenchymatous wood within a soft, thin-walled tissue, when *bark wounds* are healed by the formation of new tissue from the youngest sapwood layers, remaining on the wood body. We learn further, by studying the false annual ring (cf. False Annual Rings) and the healing processes of inner frost tears, to recognize the formation of parenchyma wood from the broken sap wood layer. Also, in the processes of grafting and especially those of budding and bark grafting we find that cicatrization tissue has been formed from the youngest sap wood, if the actual cambial zone has been injured. If the cambium is retained in an injury but the bark mantle is broken by a tear in the bark, the cambium develops into a tissue, at first parenchymatous, which, at the edge, gradually passes over into a normal wood structure, according to the amount in which the normal bark pressure is restored (cf. Wound Healing).

The same new growth can also take place on the inner side of the bark if this is raised from the wood cylinder without an entire interruption of its nutrition. I have carried out the experiment with cherries in such a way that the still smooth bark of the young trunks was loosened in strips, connected at their upper ends with the uninjured bark mantel left on the axial cylinder. At the places where the upraised strips passed over into the uninjured bark, I found the same callus formed on the inside which later was differentiated into bark and wood. It has *therefore been determined experimentally that exposed wood can produce new bark and that upraised bark tatters can produce new wood* when still attached at their upper end to the wood body.

In this way, the process in rose canker becomes easily understandable. In the first spring, a tear appears in the bark which extends to the cell rows of the spring wood of the new annual ring already formed and results in the lateral raising of the bark from the cambium as shown in the holes (*l*).

At first the constricting influence, which the cork girdle (*k*) usually exercises on bark and young wood, is wholly overcome because of this cleft, which results in a luxuriant increase of the young wood (on the under side of the figure) where the cambial zone has not been destroyed, and the luxuriant increase of the parenchyma of the inner bark where this had been raised from the young wood (at *l* on the upper side of the figure). The new structures, whether formed from bark tatters, or young wood, are uniformly callus-like and pass over imperceptibly into one another. It is these new structures which have ruptured the previously continuous bast ring (*b, b'*), have pressed outward the most strongly injured part (*b'*) and caused its death after splitting it off from the outer bark.

The main question is, in what way can the first radial cleavage have taken place. And the only answer to this can be; as the result of frost. For we again find here the browning of the pith crown, the tearing and widening of the medullary rays, the phenomena of elevation and cleavage of the tissue which I have been able to produce experimentally by the action of artificial frost. Only, I have not been able to produce artificially the secondary phenomena, viz., the luxuriant tissue increase. This probably is based upon the fact that in using artificial frosts I have not yet found the proper juvenile developmental condition. This must be the time when the cambial activity has just begun, as is evident from the small number of cell layers just formed by the new annual ring. If the disturbances occur later, capacity for reaction in the tissue is less and the excrescent cell increase does not take place. Göthe's experiments show how very determinative the time of injury is. As already mentioned, he produced excrescences resembling the canker of the grape, by a continued tapping of the grapevine in the early spring. The grape canker is closely related ontogenetically to the canker of the rose.

g. Canker of the Blackberry.

Fig. 144. Canker of the wild blackberry.

It is a noteworthy fact that, with the exception of grape canker, *all the other canker excrescences are found in the family of the Rosaceae.* In the canker of the blackberry, cauliflower-like, hard, glistening, white tissue masses with a beaded warty surface are produced on the older wood (cf. Fig. 144 *k*). These tissue masses sometimes form isolated spheres; sometimes collect in elongated, wart-like cushions, as in Spiraea. The region of the eye is the

preferred place of production. The bark is split and partially thrown back like wings.

With an abundant appearance of the canker swellings, first of all, the foliage turns yellow, then the stem begins to die back slowly from the browned eyes. By July, as a rule, the diseased branches on the same shoot, side by side with bright, perfectly green ones, have died back entirely.

If healthy plants are examined for such cankered stems, either small reddish, or brown, long ridges are found, or gaping tears often one centimetre long. I observed the same phenomenon also on many petioles. The sloping edges of such tears are covered also with cork. On these edges, small beady excrescences appear in places which consist of parenchyma and are formed from the primary bark close to the outside of the hard bast cords.

In the Rosaceae this tissue region proved to be extremely easily stimulated. I found that, after very different injuries to the bark, which generally did not extend to the hard bast, strong branches responded to the wound stimulus by a parenchymatous increase close outside the hard bast cords. Often, in the canker of the blackberry, *a place of predisposition for the formation of canker may be noticed,* for, in the spots where a wart-like excrescence had appeared, even in young branch shoots, the mechanical rings formed from the hard bast cords and other thick-walled connective elements are proved to be unthickened. A thin-walled parenchyma had appeared instead of the prosenchymatous and sclerenchymatous tissues.

The parenchymatous, excrescent tissue in the primary bark increases very rapidly and ruptures the overlying normal bark layers. In the interior of the canker wart, a porous wood body is formed which is rich in ducts. The formation of wood elements is repeated in the peripheral parenchyma layers of the excrescence zone first produced since meristematic aggregations arise from which develop tracheal wood elements, arranged like bowls or shells.

The beginning of canker in the blackberry therefore is a parenchymatous excrescence in the primary bark body which grows outward, with a cauliflower-like ramification. Only later does the tendency to hypertrophy extend backward into the inner bark, finally attacking also the wood ring which, at first, seems to have a normal structure. As soon as the swellings become older and the wood body participates in their formation, it increases to 3 or 4 times its normal size. We find similar processes in dropsy, in the formation of tuber-gnarl, etc. The canker is more rare in Rubus; as yet I have found it only in four cases and always in narrowly restricted places.

Corresponding Features in Canker Swellings.

In a survey of all the known material relating to closed canker corresponding features are found. ("Open canker" forms a transition to blight and is included here). The production of a small tear forms universally the beginning of the disease. It may be seen in all cases that the injury must

have taken place in the early spring and that the richly collected material enabled the parts surrounding the wound to form enormous excrescences most quickly. The parenchymatous character of the new structures causes a great sensitiveness to injurious atmospheric influences and especially to frost. Low temperatures, therefore, are able to injure the canker tissue in the next period of growth. The injured tissue complex can respond repeatedly with excrescent tissue, because, with its parenchymatous nature in the previous period of growth, it has stored up very abundant reserve substances in the form of starch.

The canker forms in the individual genera of the Rosaceae differ only in the manner of reaction to the wound stimulus and agree in that they prefer the bud and its immediate surroundings as the place of production. The reason for this may be sought in the division of the trunk at the place of insertion of a bud. The wood ring is always more slender here and finally traversed by a parenchymatous pith bridge.

The initial stages of the canker knot, so far as observed, i. e., the small tears usually arising near the buds, have been produced by artificial frost, but not the luxuriant overgrowth structures. This circumstance may possibly be traced back to the fact that a period in the spring had been chosen which was too late for the action of the artificial frosts.

In the healthy branches of cankered trees an abnormally increased formation of the medullary rays has often been observed, and this may indicate the explanation of the tendency to canker excrescences of certain cultural varieties, or different individuals in certain habitats, since those examples will answer most easily to a wound stimulus by hypertrophy, if their medullary, or rather bark rays, grow luxuriantly in a healthy condition.

Fig. 145. Frost spots on pear bark.

BLIGHT (SPHACELUS).

In contrast to the term "canker" which in general practice is used for the heterogeneous phenomena of a gradually extending disease, one understands pretty generally by the term "*Blight*" the occurrence of dead, black-

ish, extensive spots in the bark which have dried on the wood. In smooth barked trees, instead of large, connected blighted surfaces, numerous small depressed places in the bark are noticed, appearing often on one side of the tree. These resemble finger marks and are usually called frost plates. These injuries are abundant, or scarce, according to the susceptibility of the variety to frost and the conditions of the places of growth. In stone fruits, the phenomena of blight are found most frequently in cherries and plums; in the more sensitive peaches and apricots, the trunk usually suffers as a whole.

In pomaceous fruits, pears undoubtedly tend most easily to injuries from blight. Of forest trees, the beech and oak count as especially sensitive and in damp places the ash and acacia also. The edible chestnut is found in central Germany only in isolated localities. Among conifers, the fir seems more sensitive to frost than the spruce. The larch suffers as soon as it lacks sufficient light and air. The linden and maple are rarely found to be injured. Blight spots are found most rarely in the older birch, elm, willow, poplar, hornbean, and especially the pine.

The dying of the bark is to be considered as a direct effect of frost. It penetrates to different depths and can, accordingly, produce a different appearance in the different blight wounds. Thus, for example, frost frequently attacks only the youngest layers of the bark and sap wood, including the real cambium. The older, outer layers of the bark die only from lack of nourishment, since the bark, killed by frost, turns dark in a short time after thawing. We find in the spring (especially in pears) depressed, sharply outlined places, often only very small in extent and at first only on different sides of the trees, or branches. These places soon become dry and adhere to the wood (Fig. 145 *p*). They are the above-mentioned "frost plates" found by many fruit tree growers. A cleft appears at the boundary between the dried part of the bark and the healthy part, which is raised up by the growth in thickness of the trunk. The dead part of the bark is again cut off from its surroundings by this cleft and loses its arresting influence (Fig. 145 *r*).

The arrestment, exerted by such a dead place, lies in the increased pressure of the bark mantel so long as this bark mantel is still connected with the dead, dry, inelastic tissue. The bark pressure will be greatest near the dead places and the number of newly formed elements the smallest.

We find this at the beginning of the healing processes. The tree endeavors to cover the dead places by the formation of overgrowth edges from the healthy parts of the bark. This can take place in two ways, according to the kind of blight injury. If the branch, at the time of the frost, already has some older wood, which is browned on the blighted side but not split off, then the overgrowth edges often gradually push between the dead bark and the wood body and slowly lift the scale-like, dry brown mass of the bark. With each successive year, the overgrowth edges

approach more and more closely to one another from the sides until they finally unite, cover the blackened place in the wood and thus push out the previously attached bark and throw it off.

In Fig. 146, which represents a blighted young pear trunk, we see at the top, the old, blackened, exposed wood body which originally was covered with bark in a fresh condition; it is left light in the drawing. The bark on the whole side of the tree has been killed by frost, dried up and thrown off from the healthy part by the overgrowth edges which appear after frost. The swollen place at the base of the drawing illustrates the broadening of the flattened trunk, which occurs frequently at blighted places because of the increased formation of wood by the uninjured, adjacent tissue.

On thin twigs, the frost plates are often very small, but the wood under the dried bark is found to be split radially. The cleft, which closes after the abatement of the frost, is now rapidly overgrown; the dead bark is thrown off at once and the overgrowth edges unite. In this, the union takes place after the manner of frost ridges, i. e., the edges rise up like ridges above the normal plane of the annual ring, while the broad wounds which are closed very slowly show the axial cylinder to be flattened at the frozen place.

In both cases, however, the overgrowth edges are distinguished by the fact that they arise under the high pressure of the dead bark and, on this account, are smallest at the outermost ends and pointed like wedges. *This wedge-like growth of the overgrowth edges, which spread out over the dead surface, is a characteristic of blight in contrast to canker. The overgrowth edges of canker increase in thickness towards the place of injury and, like rolls, sink down into the open split which forms the beginning of the canker.*

It may easily be seen, that the tissues of the overgrowth edges differ according to the pressure conditions, under which they arise. This has been discussed more in detail under canker.

Fig. 146. Young pear trunk with different kinds of blight spots.

In Fig. 147, the dark place B corresponds to the frost plate p in Fig. 145; t is a piece of dead bark, the healthy part of which (R), recognizable by its white, glistening, hard bast bundles (hb), is separated from the dead tissue by a diagonal cork zone, adjoining the normal cork covering (K) at

B. The annual ring, produced after the frost, is marked *J*. If this is followed back to the place of injury, it is seen to diminish suddenly to a point and to be entirely absent under the dried, dead place in the bark (*t'*, *t*). Only the next annual ring would be able to push between these. The structure of these pointed overgrowth edges resembles much more the normal wood because of the very scantily formed parenchyma wood and the rapidly appearing thick-walled wood cells together with the ducts, than does the lip-like wood parenchyma overgrowth edges of the canker (cf. "Open canker").

In the adjoining Fig. 147 we see, above the pith bridge (*m*), the normal annual rings, interrupted by darker, sickel-shaped zones (*pz*), which here appear gray. These zones consist at times of thinner walled, ductless, shortened parenchyma cells, and at times of wood parenchyma, richer in starch. In luxuriantly growing varieties the radii of the medullary rays, which here are straight, appear somewhat bent and displace the longitudinally elongated wood cells and ducts from a diagonal to a horizontal direction.

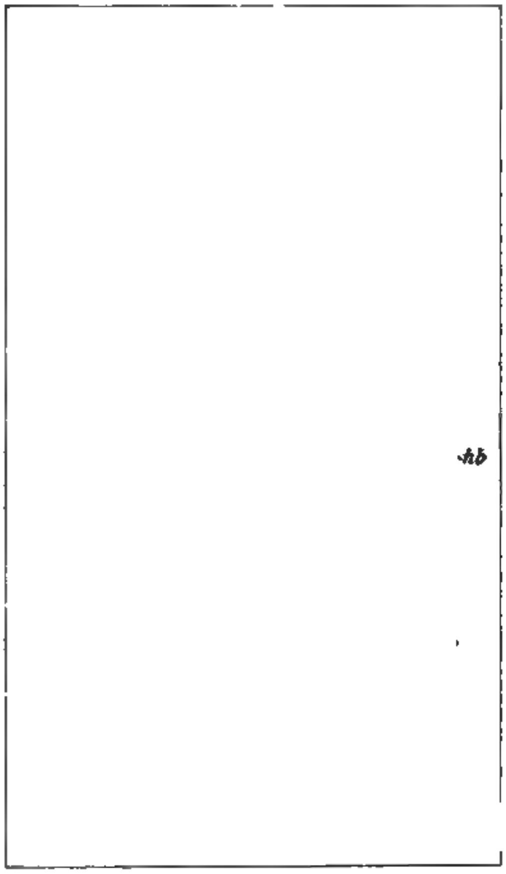

Fig. 147. Cross-section through a pear stem at a blight spot, produced by frost.

It was stated above that the frost plates should be considered as narrowly limited scald injuries of relatively small extent in *all* directions, which could, however, be found displaying all transitions up to large, blasted surfaces covering the whole side of the tree. Besides occurring in pears, such frost plates may also be found in the red beech. On branches of a beech thickly covered by such plates, the browning of the contents of individual cells, scattered through the pith, could be proved to be ***the final radiation of the frost action*** in its furthest extension into the healthy tissue. These cells undoubtedly have a different content from the other pith cells, which have remained colorless and, in cell contents, probably approach most nearly those of the medullary crown, which likewise easily become brown.

The browning does not extend into the surrounding tissue, as in wound rot, for the cells already existant, as well as those formed later in the immediate proximity of the tissue browned by frost, remain clear-walled and healthy. The browned medullary cells contain as much starch as do those not attacked, so that the brown color can not arise from a change in the starch but from some other substance. The pith does not suffer in every case. Often the wood in 2 to 3 year old branches is so browned that a yellow, gum-like filling of the ducts extends up to the medullary crown and the medullary rays also appear brown almost to the centre; the pith itself, however, having no diseased discoloration whatever. Such differences take place in different internodes of the same branch. Nevertheless, the rule holds that the initial stages of browning are found, on an average, in scattered cells of the pith, especially those of the pith crown; that, at first, only the contents and then later the walls themselves become discolored and that this discoloration of the contents seems to consist of a browning and thickening of the cell fluid. The gum-like solid masses can break in sectioning into angular pieces. I believe the filling of the ducts must be traced back in part to the hardening of the fluid contents *already existing, in this way easily explaining the often drop-like formation of the filling substance.*

With increasing cold the browning of the pith, as a rule, follows that of the medullary rays and bast parenchyma groups in the bark. In branches of the red beech frost action, limited to individual vascular bundles, can often be recognized; the discoloration is restricted to the inner half of two main medullary rays, attacking first the part of the bundle which belongs to the medullary crown and often ending suddenly with the boundary of an annual ring.

At times the wall of the duct may be found unstained or only discolored on one side, while the contents seem completely discolored. It was mentioned above that the secondary membrane can also participate in the filling of the ducts and wood cells. At first this swells up and at times, in fact, completely fills the lumen of the wood cell, or of the narrow duct, which then seems colorless and refracts the light uniformly. Besides this, cells and ducts are found which have turned a deep brown; their cell contents often lie in the form of drops or rings against the wall, but sharply separated from it. In other cases there is no separation between the cell contents and the cell wall and here the participation of the wall in the change is certain. It also may happen that only an inner layer of the cell wall turns brown, swells up and finally becomes rigid. This swollen layer then has not space enough on the inner side of the cell, or of the duct, and folds inward so that a colorless cavity is found between the brown wall layer, which has been pushed inward, and the outermost, unchanged portion.

In the browning of the cambium, which usually occurs only on one side, the contents are only slightly browned and the cell wall does not discolor at all until later. The spring wood, directly adjoining the autumn wood, seems to be most sensitive. It is evident in the bark, that the parenchymatous

cells, extending in the form of an arch from bark ray to bark ray, and already elongated, suffer less than the inner, small celled tissue which bounds them.

The observations, here mentioned, illustrate frequent, isolated cases but not phenomena of universal occurrence. Finally, a case in the sweet cherry should be mentioned as especially noteworthy. The pith of a one year old branch seemed split at one side up to and beyond the centre and the cells of the periphery of the pith grew out like filaments into the resulting cavity, similar to the woolly stripes of the apple core. No gummosis was present. The case was observed in the so-called "frost-wrinkles." It is interesting because it shows that the activity of growth in the pith, which in general occurs only in soft wood trees (Tilia), can be reawakened here.

In the above mentioned phenomena of scald is also found, as a rule, an increase of the gum centres in the Amygdalaceae and of the resin centres in conifers, with an increase of the parenchyma masses (Fig. 147 *pz*) between the normal parts of the annual ring, just as in canker. In canker, it can also be proved that the breaking up of the bark due to a *weakening of the mechanical ring* corresponds to the breaking up of the wood by parenchyma wood in the same radius. The hard bast bundles are absent from the bark of the overgrowth edges just as are the real, thick-walled wood cells in the wood of these edges.

Aggregations of Parenchyma Wood.

In canker excrescences, we have seen how tender and perishable the wood ring becomes as soon as it passes over into the overgrowth edges of a narrow cleft at the time of the greatest growth activity in the spring. Because of the rapidity of the production of such large tissue masses, the wood ring does not have time to mature prosenchymatous elements but at first is formed of parenchymatous, thin-walled elements which, to be sure, have some advantages as a storage tissue for reserve substances, but show very slight power of resistance to parasitic and atmospheric influences. It is therefore easily understandable that even in healthy trees the appearance of parenchyma, instead of prosenchyma wood, deserves especial attention from a pathological standpoint. Such cases may be found everywhere.

The aggregations of parenchyma wood can occur in the trunk in the form of scattered nests, or in ring-like bands, differing in length and width. They have been variously named. We find an enumeration of such cases in de Bary[1] , who sees in them an hypertrophy of the medullary rays. Rossmässler calls them *"Repetitions of the pith;"* Nördlinger, *"pith spots,"* while Th. Hartig[2] speaks of *"cell passages."* The most mature form is found in the so-called *"moon rings."* These are brown, or white, bands of parenchyma wood, usually extending in a ring partially or entirely around the trunk. This parenchyma wood appears at times to be decayed like

[1] De Bary, Vergleichende Anatomie der Vegetationsorgans 1877, p. 567.
[2] Hartig, Th., Vollständige Naturgeschichte der forstlichen Kulturpflanzen. 1852, p. 211.

tinder. These decayed tissue masses not infrequently give a cellulose reaction. Such tissue is often found traversed by mycelium. Th. Hartig describes the fungus as *Nyctomyces candidus* and *N. utilis.* Rob. Hartig ascribes the mycelium observed in oaks to *Stereum hirsutum* Willd[1]. In other tree genera, other fungi are found which destroy the wood and which are treated more thoroughly in the second volume, p. 385 ff[2].

In cross-sections of the wood structures termed "pith spots" appear as isolated, sharply bounded, somewhat crescent-like, browned, decayed spots, which, like passages, may be followed downward to different distances in the trunk. We owe a thorough study of these to Kienitz-Gerloff[3], who observed that in willows, mountain ashes and birches it is caused by the feeding of an insect larva. According to a review by Karsch[4] *Tipula suspecta,* Rtzb. is concerned here. This larva feeds "on the cells of the cambium and the youngest wood at the time of the formation of the annual ring." The passages, made by it, are closed as follows:—"the cells, breaking through the edges of the wound, grow quickly and divide with delicate cross-walls. At the same time, a complete closing of the cambial ring takes place and, from now on, the normal wood and normal bark are formed over the wound surface, while the cavity, perfectly independent of the new cambium, is closed by the increase of cells[5]. These injuries, due to filamentous diptera larvae, which bore their way into the cambial zone, especially at the base of the trunk and the root neck, sometimes even higher up in the shaft, and in water sprouts in May and June, are primarily considered as producers of pith spots or "brown chains" only in the varieties of trees named. Kienitz remarks that similar structures in other trees, especially conifers, do not arise from the diptera larvae above mentioned.

In regard to the pith spots of the birch, v. Tubeuf[6] confirms the investigations of Kienitz and mentions thereby that G. Kraus explains these cell aggregations as normal structures. De Bary, as was said above, speaks of hypertrophies of the medullary rays and, at the first glance, one also gets the impression that the pith spots are caused by a widening of the medullary rays. These are seen actually to become broader before they enter the aggregations of parenchyma wood and their cells take on the polyhedric, thick-walled, greatly pitted appearance of the cells of the pith spot which are filled at times with starch and brown tannic substances. In fact, it is often found that the medullary rays, when entering the pith, are broadened and unite laterally. But, supported by my "barking experiments," I consider the newly formed, filling tissue to be a product of some cell increase which can take place not only in the medullary rays but in all the tissue

1 Hartig, Rob., Zersetzungserscheinungen des Holzes, p. 129.
2 Paging in the German original.
3 Kienitz, M., Die Entstehung der Markflecke. Bot. Centralbl. 1883, Vol. XIV, p. 21 ff. Here also bibliography.
4 Bot. Jahresbericht. Jahrg. XI, Part 2, p. 518.
5 Bot. Jahresber. 1883, Vol. I, p. 182.
6 v. Tubeuf, Die Zellgänge der Birke und anderer Laubhölzer. Frostl. naturwiss. Zeitschr. 1897, p. 314.

forms composing the annual ring. The growth of the medullary, or the bark rays, only exceeds that of *other tissues in all processes of wound healing;* it thereby becomes predominate.

Also if, in the above mentioned *"moon rings,"* the boundaries between the already destroyed parenchyma wood of the annular bands and the healthy tissue are investigated, not infrequently a striking widening of the medullary rays is found, especially in oaks.

In conifers, especially pines, a still more extreme form of disturbance may be found, the so-called "ring-barking." At times, when the trunk is split, a complete cylinder, beginning at the healthy central portion of the trunk, separates from the apparently equally healthy peripheral wood, as from a shell. This takes place because the tissue is destroyed in one, and indeed only one annual ring, becomes rotten and traversed by mycelium.

This form of ring barking is distinguished by its sound, healthy core from the one studied by Robert Hartig[1] in the pine, in which a wound parasite, *Trametes Pini* (Brot.) Fr. causes the destruction of the core but does not extend into the healthy sap-wood. Hartig describes the rapid advance of the mycelium in the medullary rays and, after having discussed the destruction of the wood caused by the mycelium, the dissolution of the incrusting substances and the retention of the cellulose in the wood fibres, says that, "as the result of the collapse of the wood which is connected with this decay and loss of water, not only are radially extending cracks formed but often the outermost annual layers are loosened as a mantel from a thicker or thinner core. Thus annular clefts are produced which can have led to the name of "ring barking." We are here, therefore, concerned with a form of very extensive *red rot, or heart rot.* According to v. Tubeuf, the fungus appears also in spruces and has been observed in larches and white firs and, in America, in the Douglas fir. Emphasis should be laid on the fact that this mycelium spreads "very easily in one certain annual zone[2] and the diseased, white tissue aggregations, which now consist only of cellulose, may be found abundantly in the spring wood"[3]. This seems to me to indicate that the fungus finds greater resistance in the adjacent annual rings, i. e., the annual ring already attacked must necessarily have been more porously constructed. Accordingly, bands of parenchyma wood might contribute especially not only to infection of branch wounds by Trametes and other wood destroyers, but also to their distribution in the trunk.

False Annual Rings.

Double Rings, Etc.

Its is a well known fact[4] that the size and constitution of every annual

1 Hartig, R., Wichtige Krankheiten der Waldbäume. Berlin 1874, p. 55.

2 v. Tubeuf, Pflanzenkrankheiten durch kryptogame Parasiten verursacht. Berlin 1895, p. 471.

3 Hartig, R., Lehrbuch der Pflanzenkrankheiten. Berlin 1900, p. 172.

4 Küster, E., Pathologische Pflanzenanatomie. Jena 1903. p. 25, etc. Here also pertinent bibliography.

ring in woody plants depends upon the amount and kind of leaf activity. This has been thoroughly treated in forestry literature. Every considerable interruption in the activity of the leaf apparatus makes itself felt in the wood and can lead to the *omission of wood formation* in one side of the tree, or at the base of the trunk and in the root. If the cambium, which had been active in the spring, is incited to renewed increase in the same year after a period of inactivity, it begins the formation of a new spring wood which passes over into autumn wood, sometimes more slowly, sometimes more quickly. In this way a new, normal, annual ring is produced. In such cases are found semi-circular double rings, or others encircling the whole girth of the trunk.

We owe exact studies on this subject to Kny[1], who determined especially clearly in *Tilia parvifolia* that, after the sprouting of the buds on shoots which had been entirely defoliated by caterpillars, a second annual ring was formed. The boundary between the newly formed spring wood and the wood ring produced before defoliation is *sharp*. In Ratzeburg's[2] study we find repeated examples of the dependence of the formation of the annual ring on the time of defoliation. Since different insects can cause complete defoliation, at different times of the year, a weakening of the growth of wood is found sometimes in the same year, but, at other times, not until the following year (when the deposition of reserve substances is scanty).

In 1886, I was able to add the action of frost to the causes which can bring about the formation of false annual rings. In 1895 R. Hartig[3] published a treatise in which he described frost rings in the oak and fir and considered also a different mechanical effect, viz., *a drooping of the shoots* due to a loss of turgidity. This bending of the shoots became permanent and could be found the following year. The drooping can also occur as a result of the destruction of the pith parenchyma. In the last edition of Hartig's text book[4], frost rings from the wood of a pine and of a spruce are illustrated with the remark "in older parts of the trunk of the pine it was found that a so-called *double ring* was produced in each year of late frosts. I later confirmed the fact also in spruces and other conifers, that a late frost not only injuries the youngest shoots but even produces the 'double rings' formed in parts of the trunk which were ten years old."

O. G. Petersen[5] describes and illustrates a similar disturbance in the structure of the annual ring of beech trees which had suffered severely from frost on the 17th to 18th of May, 1901, in Holland. Nördlinger[6] had

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1 Kny, L., Über die Verdoppelung des Jahresringes. Sep. Verhandl. d. Bot. Ver. d. Prov. Brandenburg 1879. Here also discussion of earlier theories.

2 Ratzeburg, Waldverderbnis, I, p. 160, 234; II, p. 154, 190.

3 Hartig, R., Doppelringe als Folge von Spätfrost. Forstl. naturw. Zeitschrift 1895, p. 1-8.

4 Lehrbuch der Pflanzenkrankheiten. Berlin, Springer 1900, p. 220, 221.

5 Petersen, O. G., Natterfrostens virkning paa Bögens ved. Sep. Det forstlige Forsögsvaesen, I. 1904.

6 Nördlinger, Die fetten und die mageren Jahre der Bäume. Kritische Blätter f. Forst- und Jadgwissenschaft, 1865, Vol. 47, Part 2.

already observed in the normal wood formation a ring-like break in the form of a line of reddish tissue. Corresponding reports and observations may be found elsewhere which, however, do not contain any new points of view. Studies on canker phenomena increased our understanding of the disturbances in the formation of annual rings. I have proved in the apple canker that an annual ring, which is simple and normal on the healthy side of the branch, may be subdivided on the canker side into several ring zones. My recent studies on the oak have shown how such a breaking up of the tissue may take place.

EXPERIMENTAL PRODUCTION OF PARENCHYMA WOOD BY FROST ACTION.

The cases of the production of parenchymatous wood tissue instead of normal parenchyma, described in the preceding chapter as "pith spots," "parenchyma wood bands," "ring shells," etc., arise from a variety of causes which, however, as a whole, agree, in that the cambium in different parts of, or to the whole extent of the annual ring, is more or less freed from the pressure of the bark girdle binding it. It may be concluded from subsequent observations that frost, and especially spring frosts, furnish one of the most essential and frequent causes of such a loosening of the bark girdle.

In 1904, in May, a frost had so greatly injured the younger oak shoots near the edges of different forest plantations, where these bordered on open meadows, that a number of branch tips were completely frozen while only the leaves of others had blackened and dried; later they continued their growth at the tips. When these shoots, within a few weeks, had again formed new leaves, they were cut for investigation. They showed great differences in structure, among others that illustrated in Fig. 148.

We recognize an irregularly pentagonal medullary body (*m*) surrounded by slender wood rings (*h*) more strongly developed on one side. This wood ring, however, on the outside, does not adjoin a regular cambial zone, as is the case in the normal branch, but passes over suddenly into a porous, wide-celled parenchyma wood (*ph*) which becomes thicker walled toward the bark and only rarely leaves recognizable a cambial boundary zone between itself and the bark. That this girdle (*ph*) formed of porous tissue still belongs to the wood ring and has arisen from it, is proved by the short-celled, vascular elements (*g'*) scattered in the zone of thin-walled cells which, in the structure of their thickening layers, seem similar to those of the ducts in the normal, first formed wood ring, or resemble them. This presence of short ducts, or duct cells, and the condensing of the whole zone of thin-walled cells at its periphery by the occurrence of thick-walled elements, resembling the true wood cells, shows, therefore, that this branch, injured by frost, had re-adapted itself to the normal formation of the wood ring a short time after the cessation of the frost action and the formation of the parenchyma wood.

If this branch had been allowed to continue growth until frost, we would then have had a second false annual ring, as has been observed by earlier investigators and was discussed in the preceding chapter.

The bast ring (*b*) has been less affected; only the contents of the young bast cells are usually found to be brown, corresponding to the filling of the

c

r'

Fig. 148. A healed internal frost wound on a young oak branch, caused by injury from a May frost.

c cambial zone. *z* zigzag line with swollen cell walls. *g* vessels in the normal wood. Explanation of the other letters to be found in the text.

different ducts of the wood ring with a reddish yellow, gum-like substance. The bark parenchyma contains single, brown groups. No special phenomena

of discoloration are visible in the collenchymatous outer layer of the bark but may be found in the pith crown, which appears to be entirely brown. This browning decreases with the distance towards the healthier base of the branch at which the sections were made. At the base of the branch we find only scattered cells, with yellow, swollen contents.

A difference in direction of the holes thus produced becomes noticeable in the abundantly recurring cracks. Within the pith disc may be found the greatest radial extension of the holes which is seen to be connected with a peculiar, radiating formation of the pith. This is found to be distended into a pentagon, produced by the passing of the vascular bundles, composing the wood ring, out from the wood ring. As indicated above, the cause of this extension of different bundles lies in the fact that, in each of the five corners of the pith, the vascular systems, destined for the five next higher leaves, are about to make their way outward through the bark into the leaves. The pith body for the leaf lying next above the part of the branch here illustrated, is naturally furthest distended and is adapting itself to passing over, as a pith connection (*mb*), into the next bud. The bundles of the two higher leaves, lying only one or two internodes above the place of the cross-section, still lie within the complete wood ring, but even they have already formed noticeable distentions of the axial cylinder (at the right in the figure). The bundles for the 4th and 5th leaves, following the spiral of the leaf insertion, still lie entirely within the wood ring and indicate their lateral appearance only by a slight outward convexity (at the left side of the figure). Between them the pith body is continued only in the form of a broadened medullary ray and has not widened into an actual pith connection.

The holes (*l*), produced by the rupturing of the tissue, correspond in size to the amount of distention of the pith. The larger these are, and the nearer they stand to the buds belonging to them, the stronger is the radial splitting. Differing from those in the pith, we find the holes (*l'*) in the bark extending tangentially. They are produced, in part, by the throwing off of the peripheral collenchyma of the parenchyma, rich in chlorophyll, in part, however, by the rupturing of individual parenchyma cells. It should be noticed, that the formation of holes in the bark, as also the formation of thin-walled tissue (*ph-lg*), is much greater on the side of the branch where the bundle has separated most widely from the main vascular system than on the opposite side. Moreover, this also explains the fact that, in the investigation of branches injured by frost, as a rule, *one side is found more greatly affected than the other*. The natural conclusion, that the action of the frost has been greater on one side is usually erroneous. For, if a number of successive internodes are examined by series of sections, the investigator will be convinced that sometimes one side of the same branch shows a greater injury from frost, sometimes the other, according to the *position of the bud,* near which the section was made. The closer to the bud, the stronger the action of the frost in the branch.

After numerous vain attempts, the above described disturbances in tissue, and processes of healing, could at last, in the spring of 1905, be produced artificially. In April potted specimens of 4 to 5 year old oaks were brought into a greenhouse for forcing. The tender young shoots were exposed in May for one night to a temperature of 4 degrees C. below zero in a freezing cylinder. The plants were then left out of doors and investigated the middle of June. Here, exactly as in the observations made the previous year on naturally frozen oaks, the branches, injured by frost, showed very different forms of disturbance. Among them were some resembling typically the natural injuries described above; only the processes of healing, which here begin clearly at the medullary rays, were much less extensive, which may be traced to the fact that potted specimens always develop more weakly and slowly than forest trees growing in open ground. The observation was also made, that the clefts in the tissue seemed to be less extensive, the older and stronger the branch was at the time of the frost action. I conclude from this that injury from frost only leads to the formation of parenchyma wood within an annual ring when it affects very young, tender shoots at the time of the greatest growth in length. Besides this, favorable, warm weather must follow the frosty nights so that cell increase can continue at its former rate. The building material, in the form of mobilized reserve substances, is present in the branch, injured by frost, in the same amounts as before the action of the frost, but the newly produced cell elements develop differently because the conditions of tension in the branch and the resulting pressure on the cambium have become different, due to the breaking up caused by frost.

The Theory of the Mechanical Action of Frost.

The phenomena, which came to light in the above described natural and artificial frost injuries to young branches, however they may vary, can be traced to simple mechanical processes. In this we still refer to the above illustration of the oak branch in which we see that the pentagonal wood ring, surrounding the medullary disc, passes over suddenly into a light zone of delicate tissue (*lg*) and this gradually forms, toward the perihpery, tougher elements, which have the character of normal wood (*h*).

The illustrations 2 to 6 in Fig. 149 serve to orient the place of origin of the thin-walled tissue. These show enlarged portions, drawn cell for cell from the right side of the above figure (Fig. 148) at the region of the section, lying between *lg* and *b*. In all the drawings, the upper angle is the one toward the pith, the under angle the one toward the bark which, in fact (Fig. 149 *2, 4, 6*) even shows bark elements. The uppermost cell groups, in part designated by *h*, form the boundary of the wood ring which was present before the action of the frost. These pass over directly into the thin-walled tissue (*lg*) of the thin-walled stripe (Fig. 149 *2, 3*). In this, the medullary rays, which in normal wood are only one to two cells broad (Fig. 149, *5 m s*) have become enlarged and irregularly many-celled. They

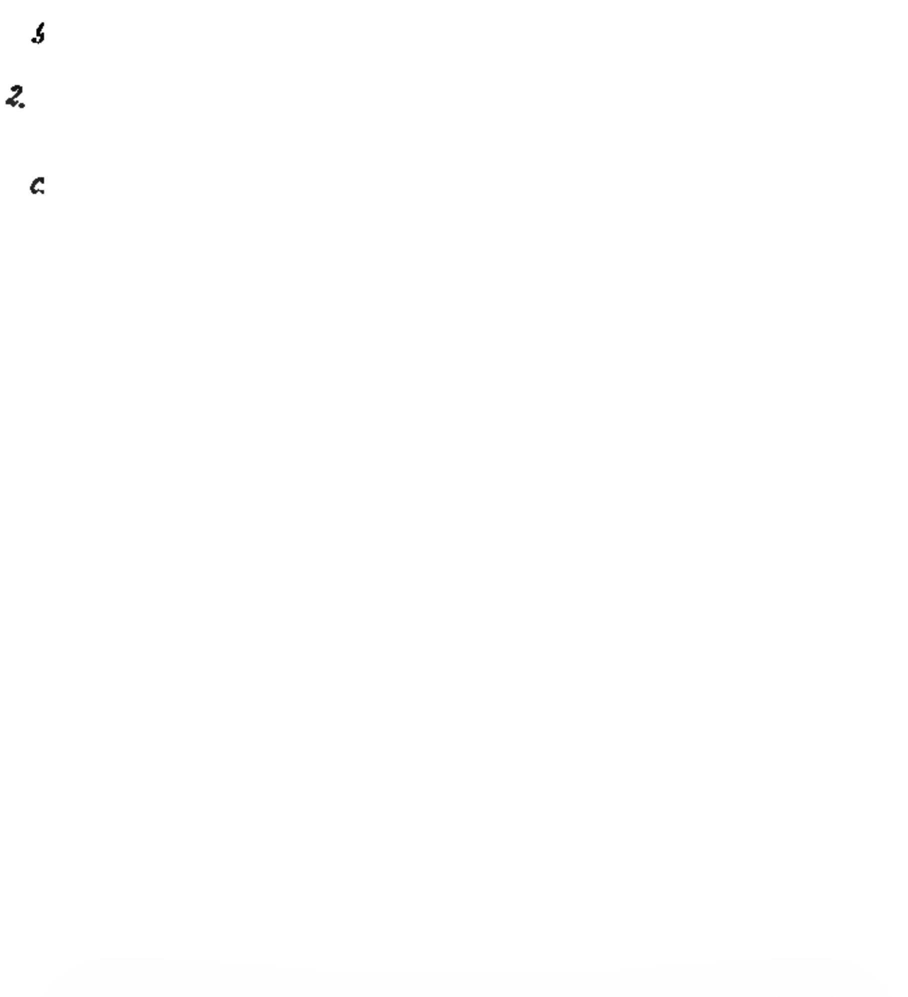

Fig. 149. Cell groups from the transitional region between the normal wood ring and the stripe of thin-walled, loose parenchyma wood, produced by frost. Taken from the zone lg-b in Fig. 148. z, in Fig. 2 and 5, indicates the zigzag lines with their swollen cell walls.

contract to their former breadth only where the porous tissue passes over into the secondary wood (Fig. 149 *2, 3, h'*) with regular ducts (*g'*). Then a normal cambial zone is formed again (Fig. 149 *2 c*) which, at the time when the medullary rays were broadened excessively, had become irrecognizable, since cell division took place absolutely irregularly in different regions of the ring of thin-walled tissue. As soon as the formation of the regular cambial zone begins again, the loose bark tissue also differentiates itself in such a way that juvenile bast groups (Fig. 149, *4 b* and *6 b b'*) again becomes recognizable.

The fact, that no dead tissue of any kind is present between the wood, matured before the action of the frost (*h*), and the looser, thin-walled tissue (*lg*), proves that the young wood, the sap wood ring, has passed over directly into the parenchyma wood of the ring of thin-walled tissue. Nevertheless, this parenchyma has retained its connection with the wood body. On this account, it is not surprising that, after the cessation of the causes which had brought about this parenchymatous formation of wood, the tissue gradually re-assumes the normal wood character and adapts itself to the formation of a secondary wood ring (Fig. 149 *2* and *3 h'*). In fact, individual elements of the sap wood, the thickening of which had advanced somewhat further at the time when the formation of parenchyma wood began, had continued the thickening of their walls. On this account, we find isolated tracheal elements (Fig. 149 *4, tr*) in the centre of the parenchyma wood.

The zone of thin-walled, porous tissue (*lg*) in the cross-section of the oak branch (Fig. 148) is, therefore, only a ***modified wood ring*** which has passed over into an excessive new cell formation. Since such a cell increase can arise only from elements which still possess their cambial nature, it must necessarily be concluded that the very youngest cambial zone elements, i. e., the sap wood, have produced this parenchyma wood. As a matter of course the real anatomical cambium, together with the young bark, has participated in this cell increase and, in this way, produced the abundant tissue in which it is not possible to distinguish where the transition from wood to bark takes place.

We now ask what may be the cause of the formation of this profuse tissue zone? The answer can only be found in the removal or weakening of the constricting, compressing influence, exercised by the bark girdle, as a whole, on the youngest tissue, i. e., the cambial region.

This cause is indicated by the holes in the bark tissue (Fig. 148 *l'*, at the right). Such tangential holes in the healthy tissue are produced by the upraising of the tissue lying above the hole from that lying beneath it. It can only be raised, however, if it has not enough room on this underlying parenchyma which is caused by a greater tangential distention. Consequently, a stronger tangential strain has occurred in these outermost tissue layers than in the adjacent inner layers of the bark.

Caspary's measurements in freezing should be recalled here. The peripheral layers contract earlier and more strongly than do the central layers. This contraction with cold is stronger tangentially than radially and greater in the delicate parenchyma than in the prosenchyma wood. Consequently, with the action of frost, there must take place everywhere within a woody axis a preponderance of tangential strain over radial contraction and, under certain circumstances, this must increase to a radial splitting of the tissue.

If the wood ring is thought of, first of all, as isolated, this preponderating tangential contraction in places of least resistance would necessarily lead to such clefts as would correspond to the gaping frost cracks in old trunks. Therefore, inner clefts must be produced from purely mechanical causes and, in fact, in the medullary rays and medullary transverse connections. Such are actually shown in the illustration of the oak branch, injured by natural frost (Fig. 148).

If we now consider the primary wood ring in its relation to the adjoining bark girdle, we must refer again to the fact that the bark girdle, of which the peripheral cells are larger tangentially than radially, contracts more strongly tangentially and, therefore, is strongly torn in this direction during the action of frost. If the frost grows less, this cracking may cease, indeed, but its effects remain, for the tissue which may thus be stretched, is not absolutely elastic and does not contract to its former volume. In this way *each frost action leaves behind an excessive lengthening of the peripheral tissue layers* in proportion to the adjacent layers which lie more toward the inside. The bark body, as a whole, therefore, is longer and either does not have room enough on the wood cylinder so that in places it is raised up from it, or it at least curves outward, i. e., *it decreases its constricting influence on the cambial elements of the wood cylinder.*

The cambial zone responds to this with a formation of parenchyma wood, as may be seen in every wound in which the bark is raised. If the bark girdle closes together again into a connected layer the cambial cylinder of the branch, by growth in thickness, must again resist the constricting effect of the bark and, on this account, again forms normal wood elements.

Thus the formation of the parenchyma wood bands in young branches comes under the same law of unequal contraction which, in old trunks, leads to the production of gaping frost clefts.

The Rupture of the Cuticle.

The experiments on potted specimens of forced oaks, mentioned in the previous section, proved the fact, not known until then, that, on superficially browned, or still green leaves, i. e., those outwardly but little affected, a repeatedly interrupted black, very fine line is formed on the under side, which gives the impression of very fine particles of soot which had settled on it in places. With a higher magnification, it is seen that this line consists of small raised places in the outermost cuticular layer which, because of its

granular condition, retains the air, and therefore appears black. The small granular papillae still remained when the leaf was destroyed by sulfuric acid; in which treatment the leaf curled up like a worm and the epidermis of the upper side puffed out in places.

This result agrees with discoveries which had been observed earlier in beech trees after natural late frosts, and which we could prove also on oaks in the open. In the production of such scarcely perceptible *rupturing of the cuticle*, some special conditions must also have co-operated which were present accidentally in the experiments but do not seem to be always effective in other experiments or in nature, for, soon after late frost, such injured oak leaves could be found in some localities but not in others. Probably a definite condition of turgor in the leaf is connected with it and this will be dependent again on the constitution of the cell contents at any given time.

A conception of the fine differences, which are decisive in frost injuries, is obtained from the observation that dead particles of tissue, injured by frost, may be found at times in the centre of the mesophyll of the leaf, which apparently is but little, if any injured. The fact that, in experiments, these cuticular breaks appear only on the under sides of the leaves may be traced perhaps to a constitution different from that of the upper cuticular covering, for it is found that in the action of sulfuric acid, the upper covering turned a bright lemon yellow, which color shade was scarcely perceptible in the cuticle of the under side.

I would like to lay especial value upon the discovery that, under certain circumstances, a rupturing of the cuticular glaze can be produced by light frost. In other breaks in the cuticle (in pomes) fungus spores were found lying in the line of the break and it may, therefore, not be out of place to assume that, in these protected places, such fungus spores have the best opportunity to germinate and to sink their germinating tubes into the organs. *In this way might, therefore, be explained the attacks upon apparently perfectly healthy leaves and fruit by fungus infection after a light spring frost.* Voglino's[1] reports might be referred to here. In 1903, after some frost in April, he found that the fungous parasites had an especially large distribution in plants injured by frost.

Thus is explained also the phenomenon of the so-called rust etchings in connected rings and irregular surfaces on our fruit. They are cork formations which have set in, in the cuticular tears, as a result of the processes of healing, while the normal cork etchings on the fruit usually begin at the stomata, or rather, the lenticels.

Protective Measures Against Frost.

(a) Snow Covering.

The process, universally used for protecting plants against frost, consists in surrounding them with substances which are poor conductors of

[1] Voglino, P., L'azione del freddo sulle piante coltivate, specialmente in relazione col parassitismo dei funghi. Atti accad. di Torino XLVI.

heat. Grapevines, roses, etc., are covered with earth or leaves, or the trunks are wrapped in moss, straw and the like. All these means are good but in cold winters, with a moderate snowfall, one should not delay throwing the snow from the streets on to the covered plants. It is well known that wrapped trunks of roses, for example, often freeze; this is explained by investigating the temperature under the covering material with a thermometer. It is found to deviate but little from the temperature of the outer air. On the other hand, if the soil under the snow covering, possibly 15 cm. deep, is investigated, it is found to be considerably warmer. Göppert's investigations[1] are the best on this subject. In February, 1870, the temperature was very low. The thermometer fell on the 4th to 12.6 degrees below zero, on an average, and yet in this, the temperature was only 3 degrees below zero under the snow covering, 10 cm. deep. The temperature of the air

on Feb. 5 was 14.7 degrees below zero, the temperature under the snow 4.6 degrees below zero,
on Feb. 6 was 17.6 degrees below zero, the temperature under the snow, 5 degrees below zero,
on Feb. 7 was 16.7 degrees below zero, the temperature under the snow, 5.5 degrees below zero,
on Feb. 8 was 16.7 degrees below zero, the temperature under the snow, 6.5 degrees below zero,
on Feb. 9 was 15.4 degrees below zero, the temperature under the snow, 6 degrees below zero,
on Feb. 10 was 14.9 degrees below zero, the temperature under the snow, 6 degrees below zero,
on Feb. 11 was 15.8 degrees below zero, the temperature under the snow, 5 degrees below zero,
on Feb. 13 was 5.7 degrees below zero, the temperature under the snow, 2 degrees below zero,
on Feb. 16 was 2.8 degrees below zero, the temperature under the snow, 1.5 degrees below zero.

The soil under the snow covering was frozen 36 cm. deep, but its temperature, even on the cold 5th of February, at a depth of 5 cm., was only one degree below zero.

It would scarcely be possible to find more eloquent proof of the usefulness of a snow covering. This explains the possibility of polar vegetation. The greatest degrees of cold in the polar zone as yet observed (40 to 47 degrees below zero) affect only the trunks of the trees which project above the snow, but not the roots. Perennial, herbaceous plants are just as little affected. These stand in a soil with a temperature under the snow covering of only a few degrees below zero. The snow covering, to be sure, does not arrest freezing but does prevent loss of warmth through radiation, the penetration of greater degrees of cold and a rapid change in temperature. But, even with us, the existence of many plants is more often connected with snow covering than we think. The freezing of seed would occur much more frequently when a long damp and moist autumn favors plant development, if the snow covering were not deposited on them, which keeps off radiation and the great fluctuations in temperature, so frequent in our latitudes. We see often enough how easily insufficiently protected, or fully

[1] Bot. Zeit. 1871, No. 4, p. 54.

exposed parts of plants freeze, if struck by sudden strong sunshine. The cell contents, suddenly struck in a condition of rigidity, the result of cold, are found poor in water content and drawn back from the cell wall, and do not have time to distend again, by absorbing water, into their normal relation with the cell wall, and, thereby, the surrounding tissues. In this way, the disorganization of the cell begins. These are the processes which occur with spring frost and are especially advantageous for garden plants.

(b) The Use of Water.

Especially herbaceous plants which are suddenly exposed to frost are benefited if the hard frozen parts of the plants are watered with right cold water and then shaded. The water on the plants freezes to an ice crust, thus raising slowly the temperature of the plant itself to zero, and it can gradually be warmed further above this temperature, after the thawing of the crust.

On the same principle of gradual warming rests the plunging of frozen potatoes and roots into a vat full of cold water and the piling of frozen cabbage heads in heaps which are then covered with straw mats.

In spring and autumn, when the air temperature does not fall to zero but the plants, because of their radiation of heat under a bright sky, cool down below zero, become covered with frost and freeze, they may be protected by substances arresting radiation. Covers and mats are spread over the plants, also very thin cloths are effective here and, if no other covering material is at hand, a thin layer of brush is very useful; even perpendicular walls have proved excellent protection against frost. They are effective, on the one hand, by keeping off the wind and, on the other, by decreasing radiation from the plants. In trees, trained against stone or wooden walls, in addition to the very considerable decrease in radiation of the trees on the side next the wall, the wall itself gradually gives up its stored heat to the benefit of the trees.

A less effective, but not entirely rejectable, protection against frost is recommended by older authors and is practical in gardens in spring. The trunks of trees are wound with straw rope one end of which dips into water. Straw and tow ropes are suspended in all directions over beds of blooming spring plants some distance above the surface of the soil, their ends being held fast by stones in a vessel filled with water.

To understand the favorable effect of this process, one should remember the great latent warmth in the water. If the water in the saturated straw ropes freezes, heat is set free which is advantageous, since it prevents the penetration of the cold to the underlying parts of the plants. Thus plants, near larger bodies of water, freeze less easily. One measure used with good results for potted plants, at a time when night frost may be feared, consists in a decreased watering, whereby the tissue of the plant

contains less water when it is exposed to the frost. A more abundant evaporation removes more heat from the plant and, therefore, heavily watered plants will cool down more than those which are less turgid.

(c) Effect of Wind.

Winds can also act favorably inasmuch as a storm begins with warmer weather, which hastens evaporation, thus removing the water from the tissues. Experimental proofs are furnished by Aderhold's experiments[1] with artificial rain. In each of six specimens of pears, which had been kept for several months in summer in a "rain chamber," five examples were found, after a winter frost, to be completely frozen and the sixth partially frozen, while of the check plants, which had stood in a dry chamber, only 2 were frozen and 4 were uninjured.

Nevertheless, no general rules can be formed in regard to the action of wind. Each locality has its own special requirements. If, for example, the statement is made that winds act favorably, this refers only to those cases where no such *permanent* effect of the wind is concerned, as is seen on sandy coasts. There the action of the roots is the determinating factor. Even if they do not freeze, they still cannot take up any more water, while the aërial portions still transpire strongly. Plants can directly dry up under such conditions. The discoveries of Höfker-Dortmund[2] are noteworthy in this connection. He protected the aërial portions less, but covered the soil, which in autumn had been loosened up about his plants, with manure or damp peat mould and watered the evergreen bushes on sunny frosty days. Because of the covering, the frost could not penetrate very far and the roots could constantly supply water to the aërial portions. In decorative planting, where the finer varieties of conifers are abundantly used, it seems advantageous, in very windy regions, to use the bluegreen forms instead of the pure green ones. Some growers maintain, in fact, that the former are more resistant.

Care should further be taken that the base of trees or plants, which throughout the year have possibly been protected by a moss growth, piles of leaves, forest litter and the like, are not exposed in the autumn in clearing up, etc. It has been found, in fact, that portions of plants matured under the protection of soil or leaves, contain a sap which freezes more easily than that of portions constantly exposed to the air. Sutherst[3] has proved this for celery, carrots, and the hearts of cabbage heads. Besides this, even if the constitution of the cell sap is not a determinating factor, at least the transportation of water is decreased in the roots and trunk

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[1] Aderhold, R., Versuche über den Einfluss häufigen Regens auf die Neigung zur Erkrankung von Kulturpflanzen. Arb. aus der Kais. Biol. Anst. f. Land- u. Forstwirtschaft. Vol. V, Part 6, 1907.

[2] Höfker. Windschutz und Winterschutz. Prakt. Ratgeber i. Obst- u. Gartenbau 1907, p. 61.

[3] Sutherst, W. F., Der Gefrierpunkt von Pflanzensäften. Biedermanns Centralbl. 1902, p. 401.

which have been robbed of their protective surroundings; they thereby cool more quickly, thus increasing the danger of drying[1].

The importance of leaving the dead litter of the plants (leaves, bunches of grass, flower stalks of the past year and the like)on seed beds and bushes until late spring is not sufficiently appreciated. Not only is their effect *as a protection against frost concerned here, but also as a protection against the drying spring winds.* Almost every year we make the discovery that plants have come well through a severe winter and evergreens have retained their leaves, but if windy, dry weather sets in a few days after the snow has melted, the leaves, which had remained juicy, dry up. It is possible that, with this rapid drying of the tissues, a similar change may take place in the protein of the protoplasma; Görke[2] proved this recently to be due to frost action. The result in many plants is a complete case of *leaf casting disease,* which is absent where protection has been afforded by the litter of the previous year. Often our most common perennial blossoming bushes, grain seeds, tree seeds, etc., are not destroyed until dried in the spring.

d. Smudge..

All these preventative methods may not be used universally in agriculture, but the use of smudges which Mayer[3] has rescued from oblivion, may deserve still more consideration from the agriculturalist. It was previously repeatedly recommended by Göppert[4] and Meyen[5] and supported by experiments. Fires which develop a good deal of smoke are ignited on the pieces of ground where injury from frost is feared. This process, which, according to Boussingault, had been largely used by the old Incas in upper Peru and is said to have repeatedly found extensive use among the older peoples, is now used again as a protection in vineyards. According to Göppert, Olivier de Serres in 1639 and later Peter Hogström in 1757 endeavored to determine experimentally the effectiveness of the process. In Würtemburg as early as in 1796 and in Würzburg in 1803, regulations existed, according to which in the autumn, when danger from frost occurred, growers were obliged to light smudges for the vineyards. In Grünberg, Silicia, this method was used for a long time, but it was given up

[1] Kosaroff, P., Einfluss verschiedener äusserer Faktoren auf die Wasseraufnahme der Pflanzen; cit. Just's Jahresbericht 1897, I, p. 75.

[2] Gorke, H., Über chemische Vorgänge beim Erfrieren der Pflanzen. Landwirtschaftliche Versuchsstationen LVX, 1906, p. 149; cit. Bot. Centralbl. 1907. Vol. 104, p. 358. The author explains the cause of death from cold as follows: The sap gradually becomes such a concentrated solution, due to the elimination of water from the cell, in the form of ice, that a precipitation of the soluble protein bodies takes place. He bases his theory on experiments with juices extracted from healthy and frozen plant parts. Fresh vegetable sap contained considerably more water soluble protein than that which had been frozen. The degree of cold at which a precipitation of the proteins takes place in extracted sap varies greatly in the different plant species. In summer barley and rye it fluctuates between 7 to 9 degrees below zero. In winter barley and rye, between 10 to 15 degrees below zero; in the needles of **Picea excelsa** it reaches 40 degrees below zero. Reactionary changes can also coöperate in freezing. The phosphoric acid, for example, as an aid, is weaker at higher temperatures, and is stronger when cooled down.

[3] Lehrbuch der Agrikulturchemie 1871, I, p. 382.

[4] Wärmeentwicklung 1830, p. 230.

[5] Pflanzenpathologie 1841, p. 323.

from a lack of general co-operation, despite the fact that, for twenty years, it had been used with good success by one proprietor. General co-operation in any region is necessary, for otherwise a single proprietor frequently does a service to his neighbor upon whose fields the wind drives the smoke, without obtaining any service in return. Special regulations for the use of smudges are not necessary. Any clear night, toward morning but before sunrise, the fires are lighted and fed with damp litter, moss, straw, etc., in which care is taken that the thickest possible smoke is carried over the fields.

Naturally the warmth produced by the fire is not effective here; it cannot be felt even a short distance away from the centre of the flame, but the smoke, like the straw mats spread by gardeners over the plants, or like clouds, is beneficial since it prevents too great cooling from radiation. We know from Tyndal's discoveries that a number of substances, like carbonic oxid gas, carbonic acid, marsh gas, ammonia, hydrogen sulfid and volatil oils, in the finest possible distribution in the air, reduced to a very small amount its capacity for letting through rays of warmth. Water vapor[1] has a like effect. Tyndal determined that this took up an amount of heat fifteen times greater than that taken up by the whole (impure) air in which it was distributed. The process is, therefore, as follows:—During the day, the sun sends its heat to us in radiant and dark rays, part of which the soil reflects, but absorbs the greater part, which it retains until the air becomes cooler than the soil. When this condition appears an equilibrium of heat tends to set in, since the earth now gives up its heat to the cool air in the form of dark rays. If, however, the lower layers of the air are strongly laden with one of the above-mentioned gases, or with water vapor, the vapor itself takes up the warmth radiating from the soil, instead of conducting it into the upper regions of the air. Tyndal shows how great the amount of heat is, which is taken up by the lower layers of air. "If we consider the earth as a source of heat, at least 10 per cent. of the heat given off by it is held within ten feet of the upper surface." By this absorption of the dark rays of heat the lower layers of the air, rich in water, form a protective mantel about the earth which, as a result, does not cool down so far as it otherwise would. The smoke produced by the fire is, therefore, an artificial covering, full of water vapor, which, in combination with the still partially unknown products of distillation, decreases the permeability of the atmosphere for the dark rays given out by the surface of the field.

We omit a special enumeration of the commercial smoke candles and bricks recently made for the purpose of producing smoke at the time of frost, since new ones will always appear with the advance in technic; reference to the existence of such articles is sufficient. It need only be mentioned that, recently, in smoking vineyards, the smudging material was carried about in carts[2] in order to overcome the blowing of the column of smoke by suddenly changing winds. The use of *smoke carts* is said to be the most

[1] Tyndal, Die Wärme betrachtet als eine Art der Bewegung. Deutsche Ausgabe von Helmholtz und Wiedemann 1867.
[2] Burger, Räucherkarren. Prakt. Ratg. im Obst- u. Gartenbau 1906, p. 128.

extensive in the town of Colmar, where a smoke department has developed and has been well organized ever since 1884. Colmar lies on a plain and the danger from frost is greater on plains than in higher regions, as was shown, for example, in 1903 in frosts in Florence. Here Passerini[1] found fruit trees and asparagus greatly injured at an elevation of 40 m. above sea level, but perfectly healthy 100 m. higher. In Colmar iron carts were used, which contained possibly 16 litres of fluid tar. After the tar had been ignited they were drawn back and forth over one field and then taken to the next place (possibly 150 m. distant). When the temperature fell to 1 degree above zero, the smoke department was notified and, at a temperature of zero degrees, the signal for lighting was given by means of gunshots. As a rule, this began in the night between two and three o'clock. The very heavy expense to which the administration was put, because of the smoke department, was paid by a tax on the harvested grapes.

We have cited this special case because we believe that only such an organization can have such sweeping results.

Frost Prediction.

On account of the expensiveness of producing *smudges* for the protection of plants, threatened by late frosts, it is naturally of the greatest importance to be able to judge in advance approximately whether night frost will occur.

On this account, it is advisable to make use of the *frost curve* constructed by Lang (Münich) (Cf. Fig. 150). This is based on psychometric observations. If, in spring, the temperature falls in the afternoon and the sky becomes clear, with a cessation of wind, the probability of night frost increases. For the use of the figure, two *exactly corresponding* thermometers are necessary. The mercury bulb of one is so wrapped in gauze that the under end of the gauze dips into water, thus keeping the cover of the ball moist. This thermometer, because of the constant evaporation of water, will stand lower than the one beside it showing the ordinary air temperature. From the difference between these temperatures the relative humidity and the position of the dew-point can be reckoned, i. e., the temperature at which the water, contained in the air as dew, mist, or rain, will be precipitated. In order, however, that these precipitations of water vapor may become effective as a protective mantel against frost danger produced by radiation, the formation of dew and mist must take place at a temperature above zero; therefore, the point of condensation must lie above zero. If this is not the case, and the air is dry, a night frost may be expected.

The mechanical manipulation will, therefore, be as follows: the height of the dry thermometer is read first of all, then the difference between this and the one with the moist mercury bulb is reckoned. The height of the

[1] Passerini. N., Sui danni prodotti alle piante dal ghiacciato dei giorni 19-20 April, 1903. Bull. soc. botan. ital. 1903, p. 308.

dry thermometer is found on the horizontal line and the amount of difference on the perpendicular scale. If the two lines, starting from these points in the scale, intersect at the right of the curved line which represents the nocturnal frost curve, i. e., intersect among the dotted lines of the scale; then no night frost is to be feared. If, however, the point of intersection appears at the left of the hypothenuse of the triangle, i. e., outside the dotted lines, night frost may be expected with certainty, in case the weather does not change suddenly and warm air currents do not cause the formation of mist or clouds. If, for example, in the afternoon, we find 8 degrees C. on the dry instrument and 4 degrees C. on the moist thermometer, this gives a difference of 4 degrees. The point of intersection of the perpen-

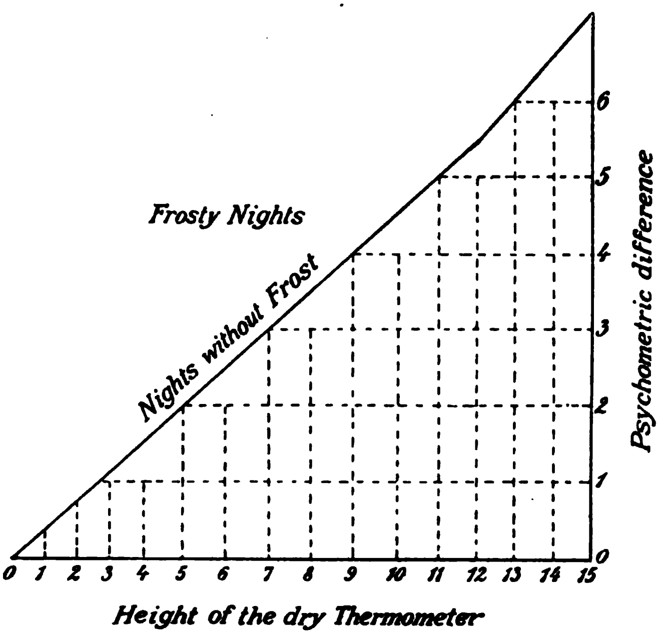

Fig. 150. Curve for finding night frosts; according to Dr. Lang, Munich.

dicular temperature line 8 with the horizontal line of a difference of 4 would be outside the dotted lines, i. e., at the left of the nocturnal frost line; therefore a night frost would be probable.

Hardy Fruit Varieties.

The more we recognize how manifold are the often outwardly imperceptible changes due to frost, which becomes apparent only in their after effects, the more important becomes the search for varieties of fruit resistant to frost. If, however, we compare the experiences of fruit growers, it becomes evident that the climatic conditions of different regions may modify the character of the variety in such a way that a variety recommended in one place as hardy is susceptible to frost in another, because of earlier development or lesser maturation of the branches. On this account,

we will name some varieties recommended as hardy for different localities, some with a continental climate, others influenced by the sea. In this list the injury to the blossom from May frosts is decisive, the condition of the wood less important, because injuries to it come under consideration usually only in less frequent, heavy winter frosts, while blossoms are exposed every year to the danger of freezing.

The difference between northeastern and northwestern Germany must be taken into consideration for German plants. In the eastern provinces the influence of Russia is felt, especially in Posen and upper Silesia, because of the invading periods of late frost. Nevertheless, we can record experiences which show that certain varieties of the more sensitive pears furnish good table fruit even in Posen. Radowski[1] lists from winter pears which have stood the test in unfavorable years: Mecheln, Rihas Seedless, Madame Verté, Winter Nelis, New Fulvie, Winter William and Dechant of Alençon.

In upper Silesia the following have stood the test[2]: Amanli's Butter pear, William's Christ pear, Bonne Louise d'Avranches, Red Bergamot, English Summer Butter pear, New Poiteau, Pastor pear and Diel's Butter pear.

Of the varieties of apple which have grown well in the district Rybnik, the following are preferred: Red Astrachan, Oldenburg, Kaiser Alexander, White Clear apple, Danziger, Hawthornden, Winter Gold Pearmin, Landsberg, Baumann, London Pippin and Kasseler.

The English varieties from the region around Kosel have been especially warmly recommended: Lord Derby, The Queen, Lord Grosvenor, Lane's Prince Albert, as well as Cellini, Hawthornden and Bismarck. The following are suitable for exposed positions and sandy soil: Brunswick Milk apple, Red Astrachan, and Oldenburg. According to Mathieu the following are especially suitable for the climatic conditions of central Germany: White Astrachan, Oldenburg, Red Eiser apple, Kaiser Alexander, Red Cardinal and, for second choice, Red Astrachan, Prinz (Downing), Baumann and Boiken. Of pears, the following have stood the test: Winter-Apothecary, Barons B., Dotted Summer Thorn, Green Magdalene, Small Long Summer Muscatel, Roman Butter pear, Spar pear, Good Gray and Archduke pear[3]. Although the danger from frost is especially great for pears, yet a May frost at the time of blossoming does not always destroy the crop. Experience shows that good crops are often obtained despite this, because generally only the opened blossoms suffer and those, developing later, produce so much the finer fruit. Besides frost, a continuous rain, at the time of the blossoming fruit trees, is especially to be dreaded.

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[1] Radowski-Schrimm, Winterbirnen für den Osten Deutschlands. Prakt. Ratg. i. Obst- u. Gartenb. 17 Dez. 1905.

[2] Langer, G. A., Die Bedeutung der Obstsortenwahl, für die örtlichen und klimatischen Verhältnisse. Deutsche Gärtnerz. 1905. No. 38.

[3] Jahresbericht d. Sonderausschusses für Pflanzenschutz. 1900 Arb. d. D. Landw. Ges, Part 60, p. 247.

For the German climate, the following varieties of plums have, on an average, best stood the test: Queen Victoria, Yellow Mirabelle (of Metz), Double Mirabelle of Nancy, the German prune and the green Reine Claude.

Of cherries, the following varieties survive the frosty days of spring in spite of their early blossoming: the common sour cherry, Ostheimer Weichsel, Double Glass cherry, large, long Loth cherry, and the Red Mass cherry.

For a more moist climate, the varieties might first come under consideration which would stand the test in Schleswig-Holstein. As such should be named the Peach Red Summer apple, Degener apple, Bath Beauty, Red June apple, Summer Spice apple, White Summer Kalvill, William's Favorite, the White Clear apple, originating from the Baltic provinces of Russia, and the English varieties, Mr. Gladstone and Irish Peach (Summer Peach apple)[1].

The majority of the above-named varieties are early apples and we think that the cultivation of early varieties must be recommended for the conditions in northern Germany. To be sure, they usually do not give first class fruit, but, with their shorter period of growth, they have the advantage of maturing earlier, the growth of their branches thus passing over into winter with riper wood which, therefore, is harder. In planting new fruit orchards, the varieties should be considered first which have already stood the test in a similar climate and under similar soil conditions. It should not be forgotten, for example, that varieties, suitable for dry climate, usually develop poorly in places by the sea, and conversely.

In regard to soil conditions, reference should be made to the fact that varieties, which grow well on light or on heavy soils, would most advantageously be chosen from nurseries which have the same physical soil constitution as is found in the place where the trees are to stand permanently. A great difference between the place of early growth and the permanent location in which the tree is planted, easily causes an arrestment in growth until the specimen has accustomed itself to the new soil conditions. The conditions are the most difficult in marshy soils, even when these have been improved by mixing with lime and the addition of ashes, or kainit and Thomas slag. Stoll[2] recommends, of the stone fruits, the common sour cherry and (with good liming) the house plum. The following apples do well. Boskoop's Beauty, Golden Noble apple, Double Pigeon, White Winter Dove apple, Boiken apple, Orleans Reinette, Gray Holland Reinette, Parker's Pippin and Purple-red Cousinot. The Gravenstein, Prinz and the Golden Pearmain grow well but are inclined greatly to canker.

Only the following pear varieties should be named: the Yat, Charneu Delicious and Great Katzenkopf. Of the small fruits, gooseberry and currants are planted on moor lands.

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1 Sorauer, Schutz der Obstbäume gegen Krankheiten. Stuttgart, Eugen Ulmer, 1900.

2 Stoll, Obstbau auf Moorboden. Proskauer Obstbauzeitung 1906, p. 182.

Just as certain regions are especially often visited by hailstorms, definite zones exist (if from other causes), especially in the mountains, in which injuries occur almost every year due to pressure from the snow. Besides these zones, some places in all regions with an abundant snowfall must be considered as especially endangered. These are depressions in the soil into which the snow can be blown from above or from the sides. Equal amounts of snowfall act differently according to the weather. If it is very cold and windy, enough snow rarely collects on the branches to cause injury; the crystals are too fine and cold to stick to one another. If, on the other hand, the weather is warm and quiet, the snow falls in great flakes and balls easily, large masses cling in the crowns of the trees and bend or break the branches.

If the trees stand on declivities, many injuries are noticed on the slope opposite the windy side; whole strips of trees can be overthrown. This occurs as a simple result of snow pressure, especially with mild winter weather and soft, open soil, while, with greater cold, the more brittle trunks will be broken (*snow breakage*). Transplanted trees, with shallow root systems, are overturned more easily than specimens well anchored by tap roots. Evergreen trees are especially inclined to break and of them the pines seem most brittle. The tougher varieties, like firs and spruces, bend more under the burden and later right themselves. Deciduous trees are less injured if the snow masses come after the leaves have fallen. Oaks and beeches, which often retain their foliage throughout the whole winter, are more endangered than other trees, provided that a previous moist and cool summer has not prevented the latter from passing into their dormant period and dropping their foliage. Here too the brittleness of the variety is decisive for the kind of injury. The trunks and branches of older acacias almost always break. In birches and alders, also, breaking may be found oftener than bending. Bernhardt[1] also calls attention to the fact that the resistance of the tree variety changes according to whether its habitat is suited to its requirement or not. For our fruit trees, the shape of the crown also enters greatly into consideration; especially in apples, for with their flat, outspread branches, a true splitting of the crowns is often found. If the tree's natural habit of growth does not form a pyramidal crown, it is advisable to cultivate artificially the development of a strong middle branch.

With avalanches, occurring frequently in high mountains, the whole effect changes according to the variety of the trees and the age of the trunk. If the standing forest is old, the trees are broken at different heights and thrown together in wild and irregular disorder. Where the trees are of different ages, the young trees are only partially pressed downward and, for a time, buried in the snow. After the snow melts, these trees right

[1] Waldbeschädigungen durch Wind-, Schnee-, Eis- und Duftbruch. Centralbl. f. d. gesamte Forstwesen 1878, p. 29.

themselves, or lean somewhat down hill, and slowly continue growth. Usually growing branches are found only on the side toward the valley, since the rolling snow masses have broken off those of the opposite side. In deciduous forests, deformed bushes develop, because of the tearing out of the roots or trunks; they look as if produced by the grazing of wild animals.

The influence of the snow covering, and of the accompanying frosts on seeds has been mentioned already in an earlier chapter. In regard to changes in temperature in the soil, reference should be made to Wild and Wollny[1]. The ice-water, produced by the melting of the snow, can not be without effect, as soon as it reaches green meadows and seeded fields. Küster[2], for example, has shown that, as a result of cooling with ice-water in the chlorophyll grains of Funaria leaves, a vacuole formation is started which results in the green pigment's lying at the edge of the vacuoles in the form of crescents.

Ice coating and icicles. The injuries from ice formed on trees are more rare. A quickly melting coating of smooth ice is usually considered non-injurious. Nevertheless, in general many growers ascribe the production of blasted specks to the deposition of ice on smooth barked branches and trunks. If, with Nouel, the production of smooth ice is considered as the solidifying of the rain drops due to the impact of striking the tree, the drops having already been cooled below zero degrees, it can be assumed that the cold of the ice acts injuriously. From the experiences collected from artificial frost experiments, I am of the opinion that the smooth ice covering can act injuriously, because of changes in tension in the ice-covered tissue. It may be proved, in very light spring frosts, that clefts arise in the bark tissue of herbaceous shoots without any extensive browning of the cell; therefore, without the chemical action of the frost having made itself felt. Such injuries to the tissues are also possible from smooth ice, if it remains for some time on the plant and especially if it outlasts the fluctuations in temperature frequently occurring with the formation of smooth ice.

It is possible to distinguish from the usual formation of smooth ice, the *ice and mist coverings* which might be compared with snow pressure because they depend upon different processes of formation. As characteristic of the phenomenon, we will consider a description by Breitenlohner[3], who made extensive observations. On January 27, 1879, precipitation began in the middle of the day, in a forest near Vienna with a complete cessation of wind and with misty weather, under an increasing air pressure and low temperature. This precipitation was half way between a drizzle and mist and soon hardened to smooth ice. A one-sided ice covering 3 to

[1] Bot. Jahresber. 1898, I, p. 584-85.
[2] Küster, E., Beiträge zur Physiologie u. Pathologie der Pflanzenzelle. Z. f. allgem. Physiologie 1904, Vol. 4.
[3] Breitenlohner, Der Eis- und Duftanhang im Wiener Walde. Forsch. auf d. Gebiete d. Agrikulturphysik 1879, p. 497.

5 mm. thick was produced on the trees, the temperature of which in all parts lay under zero. The period of the still frost lasted 5 to 6 days in this Viennese forest; the ice covering remained 9 days and increased until the thinnest branches grew to the size of a ship's rope; the beech trunks broke, while the young copse wood was bent to the ground. Since only the surface of the soil was frozen, the trees were also overthrown. The needles of the conifers especially favored the formation of ice and firs became ice pyramids, since the icicles, often 20 cm. long on the upper branches, were frozen to the lower branches.

In low positions, the covering was actually transparent, smooth ice; on the heights, however, the chief part consisted of a mixture of ice and mist. In the same way, the size of the ice particles decreased gradually from the edge of the forest toward the centre, where the covering was neither ice nor mist but had a firm, ray-like consistency, until finally, deep in the forest, it appeared as a typical mist covering, which became thinner and thinner the deeper one penetrated into the forest. In order to form a conception of the amount of ice thus produced, which also occurred simultaneously in Germany and France, the weight of the ice, hanging on a single branch, was determined with the following results: for the one part weight in a leafless cherry branch, the ice was 36.7 parts; in the Zerr oak, 44.1; in the red beech, 85.3; in the fir, 31.1; in the spruce, 51.3; in the pine, 99.0 parts.

Breitenlohner, in explaining the phenomenon, calls attention to the fact that the observations of meteorological stations, at the time of the ice covering, showed the action of a *south wind;* therefore, a moist, warm equatorial current above a cold polar stream filled the valleys. The contact of the equatorial with the polar air waves led to the unusual form of precipitation. This remained fluid because the lower, cold stream of air was not very thick vertically, so that the precipitation, coming from a warm current, had to pass only a short way through cold air.

Where the cold layer of air had a greater vertical thickness, the precipitation took on a solid form and covered the vegetation as *hoar frost.*

The precipitation, formed after the contact of two layers of air, which differ in temperature and moisture, can retain its consistency as fluid water even below zero degrees, since moist winds are splendid heat producers and carry an amount of latent warmth in water vapor which is freed during the continued condensation. Only when the cooling agent exceeds a certain amount is the mist changed into frost vapor and then the moisture elimination consists of ice needles. The peripheral trees, exposed to the free currents of air, catch and hold the mist, while, in the interior, the choked air causes the formation of the typical mist covering.

This, therefore, would be analogous to *hoar frost,* occurring with late or early frosts, and, therefore, cannot be considered to be frozen dew. Dew is condensed water vapor, which is precipitated in drops on the parts of the plant cooled down below the condensation point of the air by radiation. These drops unite. Water vapor is usually abundantly present in

the air and, as Stockbridge[1] proves, can arise as vapor during the summer months from the soil which in the night is warmer than the air. If there is a strong dew covering, it can be considered rather as a means of protection against the freezing of the plants. If this dew freezes, a crystalline coating is produced which is identical with the ice covering. Hoar frost, on the other hand, is produced when the point of condensation of the air lies below zero degrees. This degree of temperature is reached through radiation and evaporation from the plant; therefore, the mist molecules attach themselves to one another in a firm crystalline form (*soil or summer hoar frost*). The covering of frozen mist, or *winter hoar frost,* is produced by the flowing of the equatorial current into the slowly displaced polar current; the change is dangerous because, with longer duration, so thick a covering of frozen mist can be produced that the strongest trees break under its load.

In nurseries, the prompt and careful beating of the branches with sticks will prevent such an injurious accumulation of ice. This naturally cannot be carried out in forests.

In summer frosts, the cultural conditions are often of decisive significance. It should be taken into consideration, in tilled soil, that the plant body cools down more rapidly than does the soil which, in the night, acts as an equalizing source of heat and prevents, more or less, the formation of hoar frost. This effect will be the greater, the larger the water content of the soil which thus retards the cooling down. On damp fields the dew, which moderates the cooling of the leaves, is formed earlier and more abundantly than on dry soils. On the other hand, cultural regulations which prevent the rising of heat from the drier soil layers, such as the loosening of the soil, or a strawy manure, favor frost[2].

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[1] Journal of science, Vol. I, p. 471; cit. Naturforscher 1879, No. 32.

[2] Petit, M., Einfluss einiger Kulturverfahren auf die Bildung von Reif. Annal. agron. 1902, No. 7, cit. Centralbl. f. Agrikulturchemie 1903, p. 567.

CHAPTER XII.

EXCESS OF HEAT.

DEATH FROM HEAT.

Supported by numerous psychological works[1], we have arrived at the conclusion that, in judging injuries produced by excess of heat, the same points of view make themselves felt as in judging those due to lack of heat. In our cultivated plants we are confronted by constantly changing organizations. Not only has each species its special requirements as to the amount of heat which it can endure, but, even within a wide range of heat, the different individuals, in each species, and indeed their different developmental stages, behave quite differently. The individual susceptibility to a degree of heat, exceeding the optimum amount, varies according to the habitat, the supply of water and nutritive substances and the action of the other vegetative factors so that definite figures as to admissable temperature values can only have a limited validity.

We see, from this, that, in our plantations, the plants can accustom themselves to higher amounts of heat up to a certain degree. Their structure becomes different, their development more rapid, but their life processes, as a whole, still take place within the latitude of health. In regard to the different susceptibility of the different organs, according to their momentary developmental stage, we favor the theory that the part of the plant is the more resistant to an excess of heat, the richer the tissues are in cyptoplasm and the relatively poorer in water. Death from heat, like death from frost, is produced by the irreparable destruction of the molecular structure of the cytoplasmic body. We do not know in what way this takes place, nor how far a coagulation of certain protein bodies co-operates in it. The more porous the cytoplasmic body is within its specific composition, due to the in-layering of abundant water, the more easily such a destruction takes place. On this account we find that organs, rich in water, die more quickly from excess of heat. Death from heat is often preceded by a *"heat rigor,"* from which the plants can recover, when the super-maximal temperature abates, and can begin their growth again. The

[1] Pfeffer, W., Pflanzenphysiologie, 2d ed., Vol. II, Leipzig 1904.

longer the plant is left in a condition of rigor, the more slowly can it take up its activity again[1]. We will become acquainted with other main points on the subject of difference in susceptibility in the following actual occurrences.

Poor Development of Our Vegetables in the Tropics.

When cultivated plants from the temperate zones are carried to tropical regions very great disturbances become noticeable at times in the ontogeny of the plants, which severely impair the cultural aim. This lies in the undesired abbreviation of the different phases of growth, especially in the shortening of the period of leaf development, and of the production of reserve substances which are used up too early for the development of the reproductive apparatus. This is especially marked in the case of plants in which the period of growth has been prolonged by continued cultivation in soil abounding in nutritive substances, i. e., rich in nitrogen, and the leaf apparatus has been developed luxuriantly (varieties of cabbage, lettuce, etc.). We find cases of this nature reported in older works. Thus, for example, Duthie cites such a case from Saharanpur[2]. His experiments in India on plant structures show, with a few exceptions, a too rapid ripening of the seeds of European plants. While the beet (*Beta vulgaris* var. *rapa*) takes 18 months in England to complete its development, it needs in India only 8 months. In the cultivated forms of German asters, the effect of a change of climate manifests itself in the non-ripening of the seed. The blossoms of Brachycome and Petunia change and all become white. The process seems to me to represent the opposite of the process of the reddening of plant parts in spring, due to a lack of heat.

Similar phenomena have been reported from tropical America. Lehman[3] found in Western Colombia that cabbage, lettuce, onions and carrots did not develop sufficiently for cultural purposes. While seeds, imported from Europe, furnish in the first year, in corresponding localities, excellent, tender vegetables with a desired amount of development, seeds from these individuals give plants which, in cabbage and lettuce, show only traces of head formation while the onions grow out into stalks a finger thick without any tenderness, or flavor. The plants here have no dormant period.

In the level equatorial regions this phenomenon occurs sooner and more noticeably than in the higher, mountainous regions and between the 10th to 15th parallels of latitude.

Postponement of the Usual Seed Time in Our Latitudes.

We must here consider the phenomenon, not infrequently observed, that vegetables, sown too late in the year, come into the hot, dry season too

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[1] Hilbrig, H., Über den Einfluss supramaximaler Temperatur auf das Wachstum der Pflanzen. Inauguraldissertation. Leipzig 1900; cit. Just, Bot. Jahresber, 1901, II, p. 203.

[2] Gardener's Chronicle 1881, I, p. 627.

[3] Lehmann, Über eine physiologische Erscheinung bei der Gemüsekultur im tropischen Amerika. Deutsche Gärtnerzeitung 1883, p. 260.

soon, while still developing their vegetative organs. The leaf-body becomes hard and the tuber-like swellings soon become woody. Annual seed-bearing plants (grains and summer blossoms) *ripen prematurely*. Peas, sown too late, succumb very early to rust (Uromyces). Kraus[1] has already advanced the theory that the turgidity of the tissue decreases with too high temperatures.

Haberlandt, in his experimental plants, has found a splendid example of the influence of drought in fungous attacks on plants. Of three pots sown with wheat and left standing side by side during the whole period of growth, the one where the plants were watered only enough to keep up life, were so attacked by mildew (*Erysiphe graminis*) that the greater part, at any rate, of the blame for the whole failure of the harvest must be ascribed to the fungus. The pot, standing nearby and abundantly watered, was almost entirely shunned by the parasite[2]. Still more decisive is the case which I observed with *Podosphaera leucotricha Salm.* Half of a number of young apple trees in pots stood in a conservatory, the other half out of doors back of this conservatory. All the specimens had retained throughout the winter the öidia form from the previous year. The trees in the conservatory exposed, without any protection, to the summer heat were twisted out of the shape from the extensive spread of the mildew, which developed to the perithecial fruiting stage. Those standing back of the conservatories, in half shade and in moving air, lost the mildew. Hellriegel's[3] experiments prove how much the production of plants suffers from a wrong time of sowing, even without the action of parasitic enemies. Barley sown in April, May, June, August and September in pots with the same mixture of nutritive substances and soil moisture, under otherwise entirely similar conditions, behaved absolutely differently. That sown in April developed very regularly grown, excellent plants, bearing ripe seeds at the end of 88 days. The seed sown at the end of May grew into plants which, at first, also developed very vigorously, but as a long period of heat occurred toward the middle of July, at the time the heads push out from the upper leaf sheath the stalk was retarded in its growth in length. Up to the premature death of the plants (after 77 days) the kernels had matured only incompletely and remained flat; they, therefore, had become ripe prematurely. The latter sowings showed an increasing lengthening of the period of growth (the September seed, for example, required 240 days) and resulted in quite incompletely ripened grain.

In regard to forest plantations, experience also shows that the losses from transplanting of young forest trees vary according to the time it takes place. Experiments in Mariabrunn[4] gave the smallest loss in spring transplanting. For spruce trees the number of dying examples of an April to June planting increases only to decrease again in autumn transplanting

1 Molekularkonstitution des Protoplasms. Flora 1877, p. 534.
2 Biedermann's Centralbl. 1875, II, p. 402.
3 Grundlagen des Ackerbaues 1883, p. 352.
4 Deutsche Forstzeitung November 13, 1892.

(September and October). The same behavior was shown in the case of the pine, which gave a still more significant percentage of loss. In deciduous trees, as is well known, autumn transplantation is preferred.

Sunburn of Leaves in Nature.

The death of the tissue, resulting from the action of the sun, is here meant. In such cases, however, light and warmth act together. We do not know how much must be ascribed to each factor in such phenomena of death. The opinion of noted foresters, that all the light in the plant cell passes over into the dynamic force of heat and becomes effective in this form, is not very probable. My evaporation experiments with a decrease of light, and a simultaneous increase in temperature, indicate rather that at least a part of the light, as such, becomes effective, and influences the process of assimilation. A part without doubt is converted into heat and acts in that way. Upon this hypothesis, it is also probable that a plant would behave differently with the same amount of heat, according to whether it is subjected to this in a dark, or in a lighted place.

In general, temperatures between 40 to 50 degrees C. are fatal; yet Askenasy[1] has observed, with Crassulae, that they can endure uninjured such amounts of heat. Askenasy was convinced in midsummer that the inner parts of Sempervivum, at an atmospheric temperature of 31 degrees C. in the shade, had undergone a heating up to 48 to 51 degrees C. The warmth within the plants seemed higher in some varieties, lower in others, than on their outer surfaces. The temperature of the outer surface of the leaf, in different days, did not stand in any direct relation to the atmospheric temperature. *Sempervivum arenarium* showed, for example,

at 31.0	degrees C.	on the	15th	of July,	at	3:00 P. M.,	48.7	degrees	C.
" 28.2	"	" " "	16th	"	"	" 3:00 P. M.,	46.0	"	"
" 28.1	"	" " "	18th	"	"	" 12:30 P. M.,	49.0	"	"

Thin-leaved plants, standing nearby, had a much lower temperature.

The phenomena of sunburn are observed most frequently in hot-house plants which, in spring, are set out of doors. The leaf is not always killed but often only reddened or browned. In curled leaves only the convexity, on the upper side, becomes colored and, instead of being green, is reddened to a copper color (roses). In the course of a few weeks such a plant can recover even when left in this place.

I tested experimentally a similar case in spotted specimens of *Canna indica,* the greatest number of which in cloudy weather were taken from the hot house, in which they had been forced up to the unfolding of the first blossoms, and were set out of doors. Some pots stayed two days longer in the hot house and were then sunk in the earth in the middle of the day beside the specimens set out earlier. In the afternoon the upper leaves

[1] Askenasy, Über die Temperatur, welche Pflanzen im Sonnenlichte annehmen. Bot. Zeit. 1875, p. 441.

appeared striped with white, since the parts of each intercostal field farthest from the ribs, conducting water, showed dead tissue. The white stripes were broadest at the edge of the leaf and dwindled gradually toward the midrib so that it was clearly evident that the burning of the leaf occurred earliest and strongest in those regions which lay farthest away from the water conducting system of the large vascular bundles.

The epidermis did not seem essentially changed in the white places, but the palisade parenchyma which no longer had chloroplasts was greatly changed, while a transitional zone toward the healthy tissue, provided with large chlorophyll bodies arranged along the walls, showed a content still green but cloudy. In tissue, which had become white, the cell walls of which had remained clear, glycerin contracted only a small amount of the contents so that it was necessary to conclude that in this short time a large part of the contents had been used up in respiration. In the places most greatly injured, the epidermis was raised here and there, like blisters, from the flesh of the leaf (*burn blisters*) and the destruction of the chlorophyll had extended even to the under side of the leaf. After some weeks it was possible to observe a regeneration of the chloroplasts in the burned leaves in the above-mentioned transitional zones. Thus, a healing process had taken place exactly as after slight injuries from frost. The presence of mycelium could now be demonstrated beneath the burn blisters in which part of the epidermal cells seemed to have collapsed.

Rowlee[1] observed a collapse of the epidermal cells even after an 8 hour exposure to electric arc light which acted on the leaves of heliotrope at a distance of one metre; other plants (for example *Ficus elastica*), under similar conditions, remained unchanged.

In fleshy, long-lived leaves, the healthy tissue is separated from the burned tissue by a cork zone, as is shown in the subjoined illustration of a Clivia leaf injured in August from sunburn. It is easy to observe that the position of the leaf determines the place of production of the burned spot, since only those places, perpendicular to the source of heat, turned a yellowish gray and collapsed. On the following day the burned spot was perfectly brown and brittle. The youngest leaves were uninjured. The boundary between dead and living tissue becomes sharp, as soon as the burned spot extends through the whole thickness of the leaf. If, however, only the upper side of the leaf is injured, a faded, transitional zone is found. In this, the chloroplasts turn the color of verdigris, while the remaining cell contents show a yellow green. Therefore, there may occur here first of all the disappearance of the xanthophyll, while the cyanophyll remains combined in the chloroplasts. Thus, the contours of the mass of chlorophyll grains, which at first refracted the light equally strongly, become less sharp and a large amount of very fine granules give it a sandy consistency.

[1] Rowlee, W., Effect of electric light upon the tissues of leaves. Just's bot. Jahresber, 1900. II, p. 287.

Finally, the chloroplasts form groups, a dirty tea-green to a blackish green in color, which assume a cord-like form because the cell collapses. These content masses, which lie against a wall, bleach very quickly in sunshine and cause the yellowish gray color of the burned place. The cell walls do not lose their cellulose character, as is proved by testing them with chlor zinc iodide.

The healthy tissue begins at once to cut itself off from the injured tissue by a cork zone (*k*) whereby the cells of the transitional zone (*br*), which have remained rich in contents, at first somewhat enlarged by an undulation of their walls (*h*, *z*), show enlarged intercellular spaces and gradually die.

When the burned spot becomes somewhat older, it turns a deeper brown, in which the epidermal cells, which have not collapsed (*e*), participate even up to the healthy tissue. The cork zone (*k*) is produced by a

Fig. 151. Cross-section through a sunburn spot in a leaf of **Clivia nobilis.**

division and elongation of the mesophyll cells which have remained alive at the edge of the burned place. The normal cells, back of these (*p*) usually remain somewhat poorer in chlorophyll. The callous appearance of the peripheral zone (*w*) of the normal leaf part at the edge of the burned place should be noted; this is explained by the distention of the cells, which develop the cork zone, and of the mesophyll (*h*) lying in front of them, which had been injured but did not die at once.

Sunburn Spots in Conservatories.

Complaints of the occurrence of burned spots on the leaves of tender plants in conservatories abound, especially in spring, and opinions as to their production differ greatly. Sometimes bubbles in the glass are held responsible for this. Sometimes, it is thought that the drops of water, which remain on the upper surface of the leaf after the plants are sprinkled, act as burning glasses or become so warm from the sunshine that they injure

the tissue. Jönsson's[1] experiments have proved that the bubbles in the glass are actually the cause. He observed the light image of the sun's rays produced on the leaf by such bubbles and the changed position of such spots resulting from the change of the sun's position. This explains also the not infrequently observable phenomenon that such burned spots appear in regular lines.

One experiment proved, however, that sprinkling can also act dangerously, when a drop of water remained hanging on the under side of the cover glass, fastened at some distance above the surface of the leaf. In this, traces of burned spots could be produced, while drops of water lying directly on the leaf caused no injury.

To avoid such disadvantages, it would be advisable in general practice to choose better grades of glass at least for those hot houses in which valuable foliage plants are kept.

Defoliation.

Phenomena of scorching are not here concerned but rather the precipitous maturity of the tissues. In cases observable out of doors, a great dryness of the soil is usually combined with the direct action of the sun. Special experiments with burning glasses show, however, that even in damp soil the leaves are thrown off which are most strongly injured by burned spots. Wiesner[2] found that, in "the falling of leaves due to heat," those which usually fall come from the inner part of the crown of the tree, rather than from its periphery. He thinks that these outer leaves, as a result of their greater radiation of heat, do not become so warm as the leaves found in the enclosed places. We might seek the reason for this in the different vitality of the organs. Those exposed to the greater amount of light produce more substance and their cells are richer in cytoplasmic material. They have, therefore, with an abnormally increased evaporation and respiration, more reserve substances and are longer lived than leaves of the same period found in the inner part of the tree crown. Young organs in themselves are more resistant.

In cases occurring out of doors, the place of growth, together with the water supply, acts decisively. Among forest trees, this is seen best in oaks and larches in young plantations where individual specimens, already showing completely dried bunches of leaves, are always to be found between green trees which have been uninjured, or only slightly changed.

In one young larch plantation, I found that the specimens most greatly injured had lost almost all their needles from the upper branches. Only the very young shoots, the tips of which seemed twisted and a fox red, still held needles which hung downward like red tassels. The youngest needles of all

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[1] Jönsson, Bengt, Om Brännfläkar pa växtblad. Botaniska Notiser 1891. Zeitschr. f. Pflanzenkrankh. 1892, p. 358.

[2] Wiesner, Jul., Über den Hitzelaubfall. Ber. d. D. Bot. Ges. 1904, Vol. XXII, p. 501.

seemed faded, flattened and papery dry. Their extremely scanty cell contents formed a colorless ball, lying free in the inner part of the cell and turning yellow with iodine. In the older needles, the cell walls of which had remained perfectly colorless, the abundant cell contents appeared in the form of pale grayish red, or yellowish brown, uniform masses lying against the wall. The appearance resembled that produced under the influence of acid gases. In spruces too the discoloration of the needles, produced by intense summer drought, is very *similar* to that produced by *sulfurous acid.*

A similar dropping of the leaves, due to heat and drought, may also occur not infrequently in other conifers, especially when suddenly left standing alone. My experiments with spruces showed, in regard to the process of dropping needles, that when the rays from a lens were focussed at the base of the needles, these could be loosened at once with a slight pressure even if they showed no discoloration. When the needles were injured at points higher up they remained attached. In the burned places the cell contents had contracted into a band-like, green to brownish-green mass in the centre of the cell, and even their granular structure could still be perceived. The contracted content masses lay usually in the same position in the different cells, i. e., in the direction of the long diameter of the needle.

Injuries to the bud from sunburn are comparatively rare. This is to be attributed, in part, to the protection of the covering of the buds by a hairy felt, gum, resin, cork layers, or the like, which often are found to be especially effective; in part, also to the abundant cytoplasmic contents of the young tissue which, therefore, are changed with greater difficulty. In the tropics, special protective precautions may often be found. According to Potter[1], for example, in Artecarpus, Heptapleurum, *Canarium ceylanicum,* and others, the stipules of the older leaf organs serve as a protection for the young leaves until they become strong, or the entire old leaf at first forms a protective covering for the young one (*Uvaria purpurea,* Gossypium, etc.)

In peach forcing in England, *a dropping of the peach buds* has been observed. In places, where a damp cloth was stretched over the plants as a protection against the action of the sun, no dropping of the buds was found[2].

Sunburn in Blossoms and Fruits.

In injuries to blossoms, no absolutely high degree of temperature is necessary; even the usual temperatures can become injurious for shade loving plants in an unfavorable place of growth. The tuberous Begonias form the best known example, the blossom edges of which easily become brown, if the plants cannot benefit from the evaporation from moist soil.

An unusual excess of heat affects fruit in two ways. On the one hand, it produces *premature ripening,* i. e., the appearance of the processes

[1] Potter, M. C., Observations on the Protection of Buds in the Tropics. Journ. Linn. Soc. XXVIII, 1891, p. 343.
[2] Gardener's Chronicle 1893, XIII, p. 693.

of ripening at a time when the fruit should really be storing up reserve substances. The result is that the cells of the fruit flesh, insufficiently filled with reserve substances, end their life prematurely, resulting in a specked condition and premature decay when stored. In grains, a premature ripening of the blades causes a distinct injury to the kernel from an insufficient formation of starch[1].

The other form of injury consists in the direct killing of the tissues, by sunburn, on the exposed places of juicy fruits. Such burned spots frequently resemble places injured by hail because the killed tissue cannot stretch proportionately during the process of swelling of the fruit and therefore tears. In the increasing cultivation of the tomato, we now find abundant examples which remain unrecognized only because fungi usually infest the burned places of the fruit. The cases are then described as parasitic diseases.

Injury to Grapes from Sunburn.

This is of great agricultural significance. According to Müller-Thurgau's observations[2] an injury to grapes will be observed when hot, clear, sunny days occur suddenly after a longer period of cold, damp weather. It is found then, almost as a rule, that the berries of the free hanging clusters, exposed to the direct rays of the sun, lose their green color, become pale, then turn brown and finally shrivel. The stem of the cluster also begins to suffer where it is directly touched by the sun's rays. The berries, hanging to it, shrivel but, in this case, do not lose their green color. In the blue varieties, the berries, which come in contact with the sun's rays, remain green, becoming darker than those of the white varieties and turn almost black. In some years, whole bunches are found shrivelled up like raisins, producing in places a considerable injury[3]. That it is actually an excess of the heat which kills the berries in this case is shown by the fact that grapes, which were warmed in a tin case to 50 degrees C., took on exactly the same appearance as specimens attacked by sunburn out of doors. The state of ripeness, as well as the water content of the organs, and also the humidity of the surrounding air, exercises a decisive influence on the burning. Unripe Riesling and Sylvaner berries were not injured when warmed to 42 degrees C. for two hours but were injured at 44 degrees C. after an equal length of time.

Direct measurements showed that the berries, on which the sun shone, were warmer than the surrounding air. While a thermometer in the air showed 24 degrees C. in the shade and another 36 degrees C. in the sun, the temperature in the grapes, exposed to the sun, increased to 40 degrees C.

It was found further that Riesling grapes from good warm positions were poorer in water and suffered less from sunburn, than those from

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1 Déhérain et Dupont, Über den Ursprung der Stärke des Weizenkorns; cit. Biedermann's Centralbl. 1902, p. 324.
2 Der Weinbau 1883, No. 35.
3 Jahresber, d. Sonderaussch. f. Pflanzenschutz 1892. Arb. d. D. Landw. G.

inferior vineyards. Besides the small water content, the advanced ripeness of the berries is a condition which acts as a protection against sunburn. The early Malinger and the early Burgundy, which ripen even in the middle of August, for example, showed no injury whatever from the hot August sun while more than 50 different varieties of grapes, standing close by, which ripened later and therefore were still hard and green in August, had suffered more or less. Measurements of the temperature in green, unripe, hard berries of Riesling, Sylvaner, Elbling and late Burgundy showed injury at 43 degrees C., while the fairly ripe berries of the early Malinger and early Burgundy could be warmed for some time up to 55 degrees C. without injury and the flesh of the Malinger grapes was killed only at a temperature somewhat above 62 degrees C.

The discovery by practical workers that sunburn is found most frequently when wet, cold weather precedes hot days, is explained, on the one hand, by the greater water content of the berries and, on the other, by a lesser evaporation and, consequently, a lesser cooling when the air is moist. In regard to the influence of drought, Müller made an experiment on two Riesling grapes, one of which was placed in a glass vessel lined with moist blotting paper, the other in one containing some calcium chlorid, and both placed in a tin case which could be heated. The grapes in moist air were completely killed at a temperature of 41.5 degrees C., while those in the air, dried by the calcium chlorid, were scarcely injured. Two thermometers, one of which hung free while the bulb of the other was stuck into a grape berry, were put in a similar tin case, and warmed up to 40 degrees C. The thermometer, covered by the grape, constantly stood approximately 4 degrees lower than the other when the temperature increased slowly as well as when it decreased. This may well be conditioned only by the evaporation of the grape.

The phenomenon of Seed cracking can set in as the result of sunburn. Since, however, different causes of this phenomenon exist, it would be better to consider it later by itself.

At times so called *"rusty grapes"* are found, i. e., those of which the skin has formed fine cork lamellae. This has been thought to be a protective means against sunburn[1].

Protection of the grapes by the leaves is the best precautionary method and it is wrong to think grapes are helped by the removal of their foliage.

Sun Cracks.

In forest and other trees, at times in spring, the bark cracks. This phenomenon has been named Sun cracks by de Jonghe, while Caspary[2] considers them due to the action of frost. Surface dying of the bark is distinguished, *as sunburn,* from simple torn wounds. Illustrations are found

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[1] Zeitschr. f. Pflanzenkrankh. 1902, p. 111.

[2] Bot. Zeit. 1857, No. 10; "Bewirkt die Sonne Risse in Rinde und Holz der Baume?"

in R. Hartig[1] and Nördling[2]. The latter distinguishes still another "winter sunburn"[3] in which the injury to the trunk is found only at its base. The reflection of the sun's rays from the upper surface of the soil is assumed to be the cause. R. Hartig's illustration shows the lower end of the trunk of a red beech sapling with sun cracks[4]. Since these phenomena, as yet, have only been observed in the late winter and strict experimental proofs are still lacking, we maintain the opinion expressed earlier that the cracks are produced by differences in tension which arise with a sudden sharp change in temperature without the necessity of a warming of the tissue from the sun until it dies, as is the case in sunburned places. Hartig's[5] measurements of a spruce in August show how much the parts of the plants are warmed above the temperature of the air. With an air temperature of 37 degrees C. he found 55 degrees C. in the cambial region of the southwest side; only 45 degrees C. on the south side; 39 degrees C. on the east side; 37 degrees C. on the north side. The measurements were made in the afternoon after 4 o'clock.

Influence of Too Great Soil Heat.

Sachs[6] has already furnished abundant material in regard to the determination of the temperature requirements of different plants and especially with respect to the germination of seeds which had been exposed to a high temperature of air and water. In the latter connection it is evident that dry seeds endure a higher temperature without being injured than those already sprouted and that probably all plant tissue (within boundaries required by the species) is in every case the more resistant to heat the less the water content of the cells is proved to be. Corroborative works have been furnished by Haberlandt, Wiesner, Fiedler, Krasan, Just, Nobbe, Hoehnel and recent authors, in regard to which reference must be made to Pfeffer's Physiology.

Just's[7] experiments show, for example, that unfavorable results may be experienced when, in germinating seed, the temperature is increased above the optimum given for any special variety. He found in these experiments, that a prolongation of the germinating time and a slower development of the seedling is produced by too high temperatures, just as in seeds which are too old.

Prillieux's[8] older work is of importance in regard to the anatomical changes. In bean and pumpkin seeds, sown in pots in which a high soil temperature was maintained by heated wires, the following results were found: the young seedlings grew but little and with difficulty; however,

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1 Lehrbuch der Baumkrankheiten, 1st ed., p. 188.
2 Lehrbuch des Forstschutzes, 1884, p. 332.
3 Baumphysiologische Bedeutung des kalten Winters 1879-80; cit. Illustrierte Gartenzeitung 1881.
4 Lehrbuch der Pflanzenkrankheiten, 3d ed. 1900, p. 230.
5 Ibid., p. 228.
6 Experimental-Physiologie, p. 64 ff.
7 Cohn's Beiträge zur Biologie der Pflanzen. Vol. II, p. 311.
8 Prillieux, Altérations produites dans les plantes par la culture dans un sol surchauffé. Ann. sc. nat. Ser. VI Botanique, t. X, p. 347.

they looked swollen; in the places where the swelling of the little stems was most intensive, gaping, usually horizontal wounds were found which extended to the pith. In contrast to normal plants of the same age, those of the over-heated soil were only half as long but approximately three to four times as thick in diameter at the place of the greatest swelling. Here too the epidermal cells were two to three times as broad as in normal plants. The stomata showed the same difference only to a slighter degree. The hairs were not changed. The bark parenchyma was, to be sure, four times as thick but no cell increase had taken place; the cells of the pith parenchyma showed still greater radial distention; but actual cell increase could be proved only in the bast parenchyma. Prillieux cites further that the nuclei behave similarly. They hypertrophy and increase in such a way that even three or four may be found in a single cell. Nuclear division takes place by fragmentation. Such a cell increase is perceived also in the short, curved and twisted, but not swollen, roots of the changed plants. The large, deformed nuclei show usually very irregular nucleoli, occurring more than one in a cell, in which, not infrequently, vacuoles appear when colored black with osmic acid. In fragmentation of the nuclei, first a fold usually appears at one side and seems to constrict the nucleus. Later a cytoplasmic wall is formed between the two resulting nuclei. The two halves, thus produced, become inflated and tend to separate, which separation, however, does not always actually become complete. It also seems that this cleavage of the nucleus takes place within an already existing cytoplasmic covering, belonging to the original nucleus, which does not rupture until later.

This increase of the nuclei and the tender bast element may indeed indicate the way in which a higher soil temperature, which approximates the optimum, can act favorably. Cell increase and the conducting of the plastic material may be hastened. As is well known, horticulture makes good use of the beneficial influence of the higher soil temperature by means of hotbeds. Yet just here the observation may be made, that a too high soil temperature is not favorable for the many plants from a cooler climate. They do not grow more rapidly but easily decay. The assimilatory energy slackens and the weakened organism is attacked by bacteria and fungi. Hellriegel's experiments[1] show how much assimilation falls when the soil temperature becomes too high. Comparative cultures in roasted quartz sand gave yields for

at	8°	10°	15°	20°	25°	30°	40° C. constant soil temperature
rye							
Fresh weight	191.5	176.3	269.4	456.6	376.0	408.0	240.1
Dry substance ..	23.9	22.8	32.4	49.5	42.4	47.0	31.2
wheat							
Fresh weight	98.6	130.8	241.0	260.5	342.0	402.2	296.0
Dry substance ..	15.8	20.8	29.5	30.8	43.9	46.9	40.3
barley							
Fresh weight	151.9	156.0	383.4	408.5	435.2	365.0	230.5
Dry substance ..	17.1	18.0	34.4	36.7	42.0	35.0	26.3

[1] Beitr. zu den naturwissenschaftlichen Grundlagen des Ackerbaues. Braunschweig 1883. Vieweg & Sohn.

The results refer to young plants and show clearly how the production falls off toward an upper and lower limit starting from an optimum temperature for the roots. At the same time the figures also throw light upon the difference in the warmth needed by the different species. Wheat (at least when young) requires the highest soil temperature. Wheat developed the most energetic assimilatory activity at 30 degrees soil temperature, while rye developed best at 20 degrees and barley at 25 degrees C.

Also in this young stage, when adjustment to conditions is easiest, the plants clearly show the disturbing influence of too high a soil temperature. Aside from the retardation of germination, a considerable difference was shown in the habit of growth of the seedlings in that their stems and leaves at high temperatures became thin and delicate while, at lower soil temperatures, the specimens appeared short, thick and more fleshy.

The experiments by v. Bialoblocki[1] gave the same results and showed also considerable differences in the formation of the root system. The barley plants, which were kept growing constantly at 10 degrees C., soil temperature, had formed their roots from a few large, strikingly strong, splendidly white branches of the primary and secondary series, of which the latter were unusually short and covered with small, wart-like protuberances (latent eyes of the tertiary series). The individuals, standing in the soil at 30 degrees C., constant temperature, had developed unusual, richly ramified brown root fibres, as thin as threads, which had become matted to a thick felt. At 40 degrees C. the character of the root ball was the same but its extent was very small; a small felt was formed in the upper soil layers.

Tolsky[2] also found in oats a stronger development of the individual roots at a lower temperature and recently Kossowitsch[3] confirmed these results. The rate of penetration of the oats roots into the soil was retarded thereby. A soil layer of about 30 cm., at the increased temperature, was penetrated 14 days after seeding but, at the lower temperature, only after 30 days.

Also in other experimental plants (mustard and flax) the weight of the air dried roots was the greatest at a low temperature. The amount of evaporation of plants grown under such conditions was less than for specimens of similar development which had grown at the normal, or higher temperature.

Failure of the Pineapple.

The fact, that pineapples grown in European conservatories surpass imported fruit, because of increased flavor, has extended their cultivation in private gardens in some regions (for example, Silicia). The greatest danger in their cultivation lies in their "*Durchtreiben,*" i. e., a continued leaf growth at a time when the plant should enter its rest period in order

1 Landwirtschaftliche Versuchsstationen 1871, Vol. XIII, p. 424.

2 Journ. f. experim. Landwirtschaft, 1901, p. 730.

3 Kossowitsch, P., Die Entwickelung der Wurzeln in Abhängigkeit von der Bodentemperatur in der ersten Wachstumsperiode der Pflanzen. Journ. f. experim. Landw. 1903; cit. Centralbl. f. Agrkulturchemie 1904, p. 451.

to set fruit. The cause lies in the untimely supply of heat and water during the rest period of the plant, which needs three years for its development. After the plants from the sprouts (suckers) of already fruited plants have grown for two years in hot beds, they are planted in the autumn of the third year in beds close under the glass of greenhouses which are built flat purposely for pineapple growing. These beds are kept at a high soil temperature by bottom heat. When the plants are well rooted at a temperature which should lie between 25 to 27 degrees C. the heat must be decreased at least 10 to 12 degrees C. and a marked, dry period begin. Only if the plants have thus been given a complete rest, may the forcing begin again in February, when the former degree of heat in the soil is allowed to act again on the plants and the soil very soon well watered with warm water. If, after 4 to 6 weeks, the leaves of the plants begin to spread out and to become colored at the heart, it may be concluded that the fruit is setting. For fear that the decrease of temperature may injure the pineapple the moisture and heat are often not sufficiently reduced and the result is a continued growth of the plant with the exclusive production of leaves.

According to reports made by Cousins[1] the same phenomena appear in the cultivation of the pineapple in the tropics.

The Glassiness of Orchids.

Two cases may be briefly mentioned here in which plants of Oncidium developed young shoots, nearly all of which showed a glassy, translucent consistency. A few days after the appearance of the glassy places, at the base of the bulbs, the shoots fell over and decayed. Since parasites could not be found in the initial stages of the disease and the slenderness of the older shoots indicated great heat and moisture, the plants, without any further treatment, were brought into a cooler, brighter conservatory. After a few weeks, the phenomenon had disappeared.

Failure in Forcing Blossom Bulbs.

Often, after very hot summers, gardeners complain that, contrary to all expectations, the blossom bulbs develop poorly; that, when the usual temperature was used, the blossoms pushed unsatisfactorily out of the bulbs and these began to decay. Bulbs set out later than usual for forcing and cultivated with less heat, however, gave perfect blossoms.

From the different cases with which I have become familiar, I have formed the following theory: if a period of warm weather occurs in the early summer, when the bulb fields are in the midst of their most vigorous development, the foliage is killed prematurely by heat and the bulb becomes ripe *prematurely*. Under such circumstances, the material which later, in forcing, should furnish the starch dissolving enzymes, seems to be formed in insufficient amounts. If, in forcing the bulbs in winter, the usual high

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1 Revue cult. colon. 1902, No. 92.

temperature is made use of at the customary time, the stimulus of the heat for these prematurely ripened bulbs is too great, since they require a slower, more gradual sprouting with lower temperature. If this requirement is not taken into consideration, the reserve substances are not used, as normally, in nourishing the inflorescence and the bulbs decay.

Another case in which similarly the usual forcing method fails, because the temperature usually found to be best proves to be too high, is seen in the "falling over of tulips." In certain early varieties (pink blooming), it has been observed that the peduncles break over before the blossoms open. A glassy spot 1 to 2cm. long, appears below the node out of which leaves spring in these varieties (several centimeters above the neck of the bulb). The gradual shrivelling of this spot causes the breaking over of the stem.

Investigation proved an abundance of starch throughout the whole bulb body along with an unusual amount of peroxydases. In forcing, it was found, however, that with a high increase of temperature, the starch was insufficiently dissolved, i. e., too little constructive material was supplied to those forced aërial parts. The medullary tissue of the stalk, poor in contents, was torn at this glassy place, because of the rapid elongation, thus destroying the rigidity of the stalk. Bulbs, from the same shipment, which were set out some weeks later, i. e., nearer their natural time of developing and in the same temperature, developed normally. It is thus seen how the same temperature in the conservatory can act favorably at one time, unfavorably at another, according to the weather of the previous year and the constitution of the bulbs, and it is advisable at the beginning of the time of forcing to make some preliminary tests.

In lilies of the valley, the same circumstance of unusually rich starch production with an insufficient supply of starch dissolving enzymes manifests itself in the scanty development of the blossom sprays. At first only a few of the lowest blossoms of the sprays develop and only after these have withered do the upper bells open. For this reason, forced lilies of the valley often become unsalable as market plants. For such cases the process used by Garden Inspector Weber[1] of Spindlersfeld can be recommended. He watered the pips with water at 44 degrees C. before planting. At any rate, the dissolving of the reserve substances was hastened by this.

It is evident from these examples that the dormant plant parts must have reached a definite condition of maturity for success in forcing, which condition is characterized by a sufficient supply of starch dissolving enzymes.

Seed Which Has Suffered From Self Heating.

Without going into the much mooted question whether the self-heating of unripe seed, or of seed stored in a moist condition, takes place from the effects of oxydases, or from micro-organisms, as in hay[2], or from both

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1 "Gartenflora," Berlin, 1907, Part 2, p. 26.

2 Miehe, H., Über die Selbsterhitzung des Heues. Arb. d. Deutsch. Landw. Ges. Part 111, 1905, p. 76.

processes, we will consider here only the utilitarian value of the heated seed. We will mention, as example, an observation made by Bolley[1], who found in overheated wheat, stack-burned as well as bin-burned, that the embryo was browned, or entirely killed. If the grains develop at all, the tips of the leaves usually die and the roots have no hair covering. The injured grains have lost their clear color and appear pale or browned. The testa is pale and wrinkled; the flavor of the grain, as a rule, is sweetish and the germinating power, even in grain which looks good, is weakened.

The injury to the germinating power takes place so much the more rapidly the less ripened the seed was when stored or the less draughty the place of storage, since wind can dissipate the water vapor. According to Jodin's experiments[2] the use of a drying substance (slacked lime) has proved to be advantageous.

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1 Bolley, H. L., Conditions affecting the value of wheat for seed. Agric. Exp. Sta. North Dakota; cit. Zeitschr. f. Pflanzenkrankh. 1894, p. 22.

2 Jodin, V., Sur la resistance des graines aux temperatures élevées. Compt. rend, 1899; cit. Bot. Jahresber. 1900. II, p. 420.

CHAPTER XIII.

LACK OF LIGHT.

ETIOLATION.

The disease, which is produced by deficient illumination, or entire lack of light, is called *etiolation* (étiolement). The different stem members in the majority of green plants become uncommonly long and weak. According to the variety to which they belong, the leaves, as well as the internodes of the stem, either become very long, slender and limp (the majority of monocotyledons), or develop only very slightly and remain, for their whole life, in a condition similar to that in the bud (most dicotyledons).

A bleaching of the green parts of the plants, i. e., an arrested development, or decay of the existing chloroplasts, is connected with this change in form. We find exceptions only in the gymnosperms, of which the majority are unusually little susceptible to the removal of light. At any rate, according to Burgerstein[1] the absorption of the endosperm becomes slower, the epinastic spread of the cotyledons less energetic and incomplete than in the light, but—with the exception of *Gingko biloba* and Ephedra—the seedlings did turn green. Cycas and Zamia, on the other hand, cannot form any chlorophyll in complete darkness, even with a favorable temperature. Among conifers, the larches need the light most since they become only slightly green when it is excluded, while the Cupressineae become completely green.

The difference in the formation of the leaves of etiolated plants is explained by the fact that the leaf, for the most part, must nourish itself and that the cellulose material, which it needs for the new formation and maturing of the leaf cells, can be formed only by the action of the light on the very spot. If the nutriment is suppressed, the leaf cells, already formed in the bud, elongate with the absorption of water, on which account the leaf itself will become somewhat larger, but all further growth, depending on cell increase, will be impossible. The more the leaf, in its later enlargement in the light, depends on cell increase, the smaller it remains when the

[1] Burgerstein, A., Über das Verhalten der Gymnospermen-Keimlinge im Lichte und im Dunkeln. Just's bot. Jahresb. 1900, II, p. 250.

light is shut away. Further, it will develop so much the less, the fewer the cells originally formed as leaf primordia at the tip of the stem; a clasping leaf, on this account, will develop further than a whirl leaf can, because, in the primordia of the former, the whole circumference of the stem is active, while in those of the latter, the cells at the same height on the stem must be divided among as many leaves as the whirl numbers. A further point, which must be of influence on the development of the leaf in the dark, is the distance of the leaf primordia from the source of the reserve substances. Those produced first, and lying nearest a reserve substance store, remove more material from the supply and, on this account, become larger than those produced later and higher up on the etiolated stem. Thus the development of the etiolated leaf is dependent on the individual primordia and on the amount of nutrition to be found in its immediate proximity.

The primordia of the monocotyledon leaves, in the majority of cases, are formed like a roll, surrounding the stem, below the vegetative cone and in the immediate proximity to reserve substance stores, when these are present, from which the dissolved constructive material has to pass only a short distance through the shortened axis (grasses).

Having discussed the etiolation phenomena of the leaf, the unusual elongation of the etiolated stem members remains to be explained. We will follow in this the statement made by Kraus[1]. As a rule, etiolated stems are thinner than normal ones, caused by a lesser number of cells, and this deficient activity in the cambium of the stem is explained by the assumption that some of the nutritive substances, worked up by the leaf, which pass over into the stem through the petiole, pass further in a radial direction and help to nourish the cambium of the internode of the stem. If this source of nutrition fails, i. e., the leaf, which in the dark remains in the form of a scale, is not in a position to obtain material for cell increase, the stem member remains as it is without any actually new cell formation. The thickening of the cell walls is also suppressed. In normal stems the parenchyma cells of the bark and the prosenchyma cells of the wood become thickened during their growth in length. The pith cells, however, begin to grow thicker only when elongation is approximately at an end, i. e., at the latest moment, since they are only reached by the cellulose micella, wandering in a radial direction from the leaf into the interior of the stem, when it is no longer used to thicken the wood or bark cells. In etiolated stems, because of the lack of nutrition, the thickening of the cell is only indicated, so that it is almost lost in those which lie between the different vascular bundles and, in the normal condition, develop into wood cells. On this account, frequently no closed wood ring is found in the etiolated plants. The loss in thickness suffered by these cells is compensated for by their greater length, which exceeds that of the normal cell from two to four times.

[1] Kraus, C., Über die Ursachen d. Formveränderungen etiolierender Pflanzen. Pringsheim's Jahrb. f. wiss. Bot., Vol. VII, Part 1, 2, p. 209 ff.

This excessive length is explained by the modified tension conditions in the stem members.

The bark, if loosened from the growing part of the stem, contracts; the isolated pith body, on the other hand, becomes considerably longer. It is evident from this that, in the stem, the pith is really the elongating factor, while the rest of the tissue represents the restraining factor. Only when the stem is still very young can the pith satisfy the impulse for elongation because the surrounding tissues are still thin-walled and very easily stretched. They can, therefore, most easily follow passively the strain which the pith exercises. Gradually, however, the elasticity of the outer tissue is entirely lost and the longer pith is now restrained by the thick-walled bark and wood elements. In the latter developmental stage, shortly before the stem member ceases growing, the differences in the tissue are equalized, for now the pith cells grow broader rather than longer, as a result of the restraining influence of the bark layers and, in this form, become stable since the porous thickening layers are now formed in the cell wall.

Therefore, the longer the bark elements remain elastic, so much the longer can the pith follow its impulse to elongate and draw the other tissues out with it.

The etiolating plants often resemble juvenile organs and the condition of etiolation; up to a certain degree, can be designated as a permanent juvenile form.

After discussing the morphological changes, we have still to consider some metabolistic processes. First of all we will mention the investigations of E. Schulze and N. Castoro[1] on *Lupinus albus*. In etiolated seedlings, the protein content decreases constantly, while asparagin increases; tyrosin and leucin decrease. At any rate, seedlings grown in the light retain for a long time a high amount of asparagin but contain very little amino acid.

Palladin's[2] experiments make it evident that the decreased current of transpiration in etiolated plants causes a too slight absorption of mineral elements, especially calcium. A lack of calcium salts, however, even in leaves rich in proteins, prevents all further development.

Wiesner[3] has shown by numerous experiments that plants grown in the dark are less resistant to atmospheric influences. He found, for example, that seedlings, grown in the light, are much more resistant to the action of rain and water in any form, than seedlings developed in the dark.

Observations made by Maige[4] on Ampelopsis and Glechoma show how the material differences come to expression in growth. Diffused light

1 Schulze, E., u. Castoro, N., Beiträge zur Kenntnis der Zusammensetzung und des Stoffwechels der Keimpflanzen. Zeitschr. f. phys. Chemie, Vol. XXXVIII. Cit. Botan. Centralbl. 1904, No. 47, p. 540.

2 Palladin, W., Eiweissgehalt der grünen und etiolierten Blätter. Ber. d. Deutsch. Bot. Ges. Vol. IX, p. 194. — Ergrünen und Wachstum der etiolierten Blätter. Ibid. p. 229.

3 Wiesner, J., Der Lichtgenuss der Pflanzen. Leipzig 1907, W. Engelmann. p. 260.

4 Maige, Influence de la lumière, etc. Compt. rend. 1898, p. 420. Cit. Bot. Jahresber. 1898. I, p. 587.

furthers the formation of the leaf shoots and can, in fact, cause the transformation of an inflorescence bud into a climbing branch. Direct sunshine has an exactly opposite effect.

Green's experiments[1] are very important for pathology and especially for the point of view which we would represent, that a whole series of diseases is caused by a change in enzymatic functions. He confirms the observations of Brown and Morris that the supply of diastase in the foliage is diminished after a period of bright illumination. The ultra violet and adjoining visible rays are especially important in producing such an enzymatic decrease. Such an enzymatic destruction by light may be compared with the well-known killing of bacteria by light.

Shading.

In agriculture, the injuries produced by direct etiolation are much less frequent and, on this account, less significant than the lower grade of occurrences which arise from an insufficient supply of light; i. e., *too strong shading,* and make themselves felt in the decreased production of useful substances. Stebler and Volkart[2] have made measurements of the removal of light caused by different trees. With a clouded sky, they found a decrease of light from the pine of 50 per cent.; from the birch, 56 per cent.; from the cherry, 78 per cent.; from the oak, pear and apple, 82 per cent.; and from the beech, 95 per cent.

Since each plant has its definite need of light, cases also occur in which cultivation gives an excess of light, while the natural habitat would furnish the plant with only a subdued amount. This is found in many of our hop fields and in strawberry culture[3]. In such cases, shade causes an increased production but, in the majority, reduces the amount of dry substance and weakens the color of the foliage and blossoms. The question of shading may be of especial importance for our colonial plants. In Java, as well as in our East Africa colonies, coffee plantations suffer very frequently and Zimmerman[4] ascribes this to a lack of shade trees which would prevent over-production by the coffee trees; for example, in Usambara, this has already caused great injury. It is probable that the consequent lessened strength of illumination, besides the protection from the wind and decrease of temperature, especially favors the thriving of coffee.

The decreased harvest from plants which need light, due to the influence of the *shade of trees,* arises not only from the limited amount of light but also from the lesser warming of the soil. E. v. Oven's experiments[5]

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[1] Green, J. Reynolds. On the action of light on diastase. Phil. Trans. of the R. Soc. of London. Ser. B. Vol. 188; cit. Bot. Jahresber. 1897. I, p. 89.

[2] Stebler, F. G., u. Volkart, A., Der Einfluss der Beschattung auf den Rasen. Landwirtsch. Jahrbücher. d. Schweiz. Bern 1904; cit. Bot. Centralbl. 1908, Vol. 101, p. 60.

[3] Taylor, O. M., and Clark, V. A., An experiment in shading strawberries. New York Agric. Exp. Sta. Geneva Bull. 246, 1904.

[4] Zimmerman, A., Einige Bemerkungen zu dem Aufsatze von Fr. Wohltmann, usw. Berichte über Land- u. Forstwirtschaft in Deutsch-Ostafrika. Vol. I, Part 5, 1903.

[5] v. Oven, Über den Einfluss des Baumschattens auf den Ertrag der Kartoffelpflanze. Naturw. Zeitschr. f. Land- u Forstwirtschaft. 1904, p. 469.

show how great the differences can be. He found an average temperature of 22.26 degrees C. at 9 A. M. on ten days in August, in soil on which the sun shone, but, under a cherry tree, a temperature of 19.06 degrees C. In 1884, Wollny[1] had already measured the influence of soil shading due to *weeds* in a potato field and found, at a depth of 10 cm. in the soil, that the temperature averaged 2.6 degrees C. less than on a field cleared of weeds.

Besides the temperature, the amount of water in the soil is of importance. Gain's measurements[2] show how much the soil moisture influences the size of the leaf. He reckoned the length of the organs set in a dry habitat at 100, the dimensions on damp soil for barley were 240; for poppies 550; for potatoes 150.

If the plants continue to have too little water, their maturing is naturally delayed; their productivity is also considerably reduced. In this connection Bimer's experiments[3] should be mentioned. He found that the ripening of potato plants was delayed 8 days in a soil with a 40 to 30 per cent. saturation capacity; 18 days in a 30 to 10 per cent. saturation capacity in contrast to plants with an abundant soil moisture (80 per cent. saturation capacity). With the same high moisture content of the soil, Wollny harvested 80 g. of tubers from pot plants, while he obtained only 39 g. with half the water content of the soil and only 19.5 g. with 20 per cent. saturation capacity.

In growing herbaceous plants with shallow spreading roots, the yield is markedly decreased by the deeper lying *tree roots*. In v. Oven's investigations, the water content under a cherry tree amounted to 20.24 per cent., in the unshaded vicinity, however, it amounted to 21.78 per cent. According to Wollny, 2.86 per cent. more water was withdrawn from a potato field by the weeds than by the potatoes alone.

v. Oven describes the influence of shade on the plant itself, according to his own observations and those of other scientists. The stem members become longer; the leaves more slender and the ripening is retarded. The epidermis, the sheath of the vascular bundles, the walls of the ring ducts and medullary parenchyma are not so thick and the lignification is less.

The cause of the lengthened period of growth of plants in the shade must be looked for in the lesser intensity of metabolism, which manifests itself in the weaker respiration, since, according to our experiments, the amount of assimilatory activity, under otherwise equal conditions, determines the degree of transpiration, and this also explains the essentially lesser evaporation, and, on this account, the higher water content in shaded plants.

Of the numerous experiments, which determine a reduction of the harvest due to shade and which v. Oven cites, in addition to his own, one by Wieske on a wheat field is of interest. The plants, which were shaded for the greater part of the day by fruit trees, gave a grain yield decreased

[1] Wollny, Forschungen auf dem Gebiete der Agrikulturphysik, Vol. VII, p. 349.
[2] Bot. Centralbl., Beihefte. Vol. IV, p. 418.
[3] Bimer in Biedermann's Centralbl. 1881, p. 154.

about 30 per cent., and a straw yield about 32 per cent. less than the unshaded plants in the same fields.

The results which Pagnoul[1] obtained are especially noteworthy. In experiments with sugar beets, he found a strong falling off in sugar content with an increase of the leaf substance per gram of root body and, for potatoes, a decreased tuber yield with a significant falling off of dry substance. Besides this, however, he proved that the nitrate content for beets and potatoes, grown under blackened glass, was more than ten times as great in the leaves and roots as in plants grown in the sunshine. Therefore, the physiological activity was changed in the shade since the ***nitrates were not sufficiently used up.***

Some of v. Oven's experiments took up the measurement of the intensity of the light which remained after the sun's rays had passed through a tree crown. It was shown by the Bunsen-Roscoe method, that the proportion of full daylight to the amount of light under fruit trees was about 1 to 0.3. The shade of apple trees reduces the intensity of the light, on an average, from 1 to 0.234; the shade of pear trees from 1 to 0.233; that of cherry trees from 1 to 0.345.

For practical purposes, the lesson may be drawn from existing observations that the cultivation of fruit trees between field plantations, so widely recommended, is unprofitable for northern regions. For southern countries, in which an excess of light and heat may at times injure the plants, the method will be advantageous. We find this theory confirmed by the fact that in Italy the fields are divided by rows of mulberry and olive trees, as well as by grapevines. According to Linsbauer[2] the cultivation of grapes in Italy (on pergolas) and in Austria (on low stakes) has been determined by adaptation to the light conditions. In southern regions, the longer duration of the sunshine permits the shading method of growth on arbors, while, in northern countries, the shorter period of sunshine must be fully used.

Like Frank-Schwarz, we reproduce illustrations of beech leaves from Stahl's well-known studies on the structure of shade leaves. In Fig. 152 may be seen a beech leaf grown in the sun, in Fig. 153, one grown in half shade; and in Fig. 154, another matured in strong shadow. We see from these how the leaf decreases in size with deficient illumination. The palisade cells (*pp*) are formed in a less characteristic way, the spongy parenchyma (*schp*) becomes especially reduced and the vascular bundle cords weaker; a more feeble bud development is coordinated with the lesser leaf development.

The formation of the tissue, especially the differentiation in the parenchyma tissue[3], depends upon the light intensity in the spring. Hesselman[4]

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[1] Annales agronomiques, Vol. VII, 1891; cit. v. Oven.
[2] Wiesner, Lichtgenuss der Pflanzen. 1907.
[3] MacDougal, D. F., The Influence of Light and Darkness, etc.; cit. Bot. Centralbl. 1903. Vol. XCII, p. 296.
[4] Hesselmann, H., Zur Kenntnis des Pflanzenlebens schwedischer Laubwiesen. Beih. Bot. Centralbl. Vol. 17, 1904, p. 311.

found that the plants, completing their development in a constantly reduced, but not especially small amount of light, show a much scantier formation of the assimilatory tissue than those specimens which have a good deal of light in the spring but are strongly shaded in summer. With an equal amount of leaf surface, plants grown in the sun, with their matured palisade parenchyma, transpire considerably more strongly than those grown in the shade[1]. According to Ricôme[2], the palisade cells are said to be taller but narrower, the vascular bundles more abundant in the petioles. The same difference is found between specimens grown out of doors and in conservatories[3].

Investigations made by Count zu Leiningen[4] give us a satisfactory insight into the amount of work performed by light and shade leaves. He

Fig. 152. Cross-section through a beech leaf matured in the sun. (After Stahl.)

Fig. 153. Cross-section through a beech leaf from a half shaded position. (After Stahl.)

Fig. 154. Cross-section through a beech leaf from a very shady place. (After Stahl.)

pp palisade parenchyma, *sch* spongy parenchyma

found in the beech, reckoned on the same amount of leaf surface, a considerably smaller content in pure ash (with the exception of silicic acid) in sun leaves than in shade leaves; the nitrogen content was corresponding. We explain this condition of affairs as follows:—the root system provides the leaves with equal amounts of mineral substances; it now depends upon

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[1] Bergen, J., Transpiration of sun leaves and shade leaves of **Olea europaea** and other Orval-leaved evergreens. Bot. Gaz. Vol. 38, 1904, p. 285.

[2] Ricôme, R., Action de la lumière sur des plantes étiolées. Rev. gen. de Bot. 1902, t. XIV, p. 26.

[3] Küster, Review of "Bédélian, Influence de la culture en serre, etc.," in Hollrung's Jahresber. über Leistungen auf d. Geb. der Pflanzenkrank. Vol. VII, 1905, p. 7. (Further notes on Sun and Shade Leaves, cf. Küster, E., Pathologische Pflanzenanatomie 1903, p. 24, etc.)

[4] Leiningen, Wilhelm, Graf zu, Licht. und Schattenblätter der Buche. Naturw. Zeitschr. f. Land- u. Forstwirtsch. 1905, III Year, Part 5.

how these are made use of. *The more vigorously a plant grows, the more organic substances it produces per gram ash.* Therefore, a lesser assimilatory activity must be concluded each time, if the analysis proves a high ash content in proportion to the dry substances. In the present case, the scanty amount of light is the factor reducing production.

Sensitiveness to shade is, at any rate, connected with a definite limit of value for each plant variety, but, as in all factors of growth, these values can shift individually to a certain degree, so that, in the same species, there may be races very sensitive to shade in which, in Nordhausen's[1] opinion, certain reduction phenomena become herditary.

Each leaf in the plant has its special sensitiveness to shade, according to the light conditions under which it was produced, and its position on the axis. The shade produced by leaves higher up is the most important. The amount of assimilation and respiration, as well as of transpiration, is determined by this. In Griffon's experiments[2], for example, it was found that a leaf, as thick as that of *Prunus Laurocerasus* is not able, in direct sunlight, to completely prevent the carbon dioxid decomposition in the leaf of *Ligustrum ovalifolium.* Under two such leaves, however, the development of carbon dioxid took place. Under such conditions, therefore, assimilation was so reduced that respiration exceeded it.

It naturally depends also upon what color the shaded plant parts are, i. e., which light colors can still pass through them.

According to Teodoresco[3] the leaf tissues develop most poorly in green light; they are found to be better in red light; the best development, however, is found in blue light, and, therefore, the greatest enlargement. The chlorophyll grains are also smaller in green light, less numerous and not so regularly distributed as in red and blue light.

The product of the activity of the chloroplasts, corresponding to their development, is proved especially favorable in the most strongly refrangible rays. Palladin[4] exposed etiolated cotyledons of Vicia in sugar solutions to white and colored light and found that the assimilation of the sugar, as well as the formation of active proteids, took place most vigorously in the more strongly refrangible light rays and, therefore, respiration was more intensive.

If the leaf, because of a scanty light supply, cannot work any longer, it falls off, just as under the action of all other factors which suppress its assimilatory activity[5]. This explains the regular *"summer leaf fall,"* which, naturally, is different from leaf fall due to heat. Wiesner[6] explains the

1 Nordhausen, M., Über Sonnen und Schattenblätter. Ber. d. Deutsch. Bot. Ges. Vol. XXI, 1903, p. 30.

2 Griffon, Ed., L'assimilation chlorophyllienne dans la lumière solaire qui a traversé des feuilles. Compt. rend. CXXIX, Paris 1899, p. 1276.

3 Teodoresco, E., Influence des différentes radiations, etc.; cit. Bot. Jahresber. 27. Jahrg. 1901. Part II, p. 133.

4 Palladin, W., Influence de la lumière, etc.; cit. Bot. Jahresber. Jahrg. 1899, II, p. 134.

5 Vöchting, H., Über die Abhängigkeit des Laubfalls von seiner Assimilationstätigkeit. Bot. Zeit. 1891, Nos. 8 and 9.

6 Wiesner, Jul., Über Laubfall infolge Sinkens des absoluten Lichtgenusses (Sommerlaubfall). Ber. d. Deutsch. Bot. Ges. Jahrg. XII, Part 1, 1904, p. 64.

"summer leaf fall" in that the lowering of the daily light intensity, following the beginning of summer, brings about a lowering of the (absolute) amount of light, for the plant concerned, below the minimum, whereby an immediate loosening of the leaves is caused.

The amount of bloom for each plant depends, of course, upon the abundance of the carbon assimilation, hence shaded specimens bloom less. Exclusively diffuse light delays the time of blooming and can prevent the complete ripening of the fruit, so that the seed will atrophy[1].

There are cases where plants, with a previously abundant assimilation, are placed in the shade before their blossoms develop. In the dark, the blossoms appear later, as a rule. Their color is paler and at times white; their size and amount of substance less and the peduncles not infrequently longer[2]. If however, the leaves are left in the light and only the branches, bearing the blossom buds, are darkened, then, according to Kraus[3], the flowers, with a few exceptions, develop completely.

We have considered in the previous section the thin-walled condition of the cell elements in etiolated plants.

THE LODGING OF GRAIN.

The lodging of the stalks for a long period effects a loss in quantity and quality of the harvest. It is the more dangerous the more the bending of the stalk approaches actual breaking over. Investigators were inclined earlier to assume one single cause for this lodging until later observations determined that very different factors can come into effect and that, according to the causes, the breaking over of the stalk takes place sometimes at the base in the soil, sometimes close above this point, or higher on the stalk.

Thus we know now that frost injuries often produce weakening of the stalks which without, or (usually) with the later co-operation of some fungus, initiates their falling over. Further, eating by insects, breaking from the wind, hail, long continued rainfall, not infrequently cause a direct falling of the stalks.

While, however, the majority of the factors named cause a lodging of the grain in spots so that stalks remain standing upright between these places, the actual lodging most feared by the agriculturalist is the one occurring in continuous areas, due to weak development of the bases of the stalks.

L. Koch[4], who has definitely shown by experiments that this results from a lack of light, produced artificially the phenomena of lodging by shading the stalks. The experiments made earlier by Gronemeyer[5] were

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1 Passerini, N., Sopra vegetazione di alcune piante alla luce solare diretta e diffusa. cf. Just's Jahresber. 1902, II, p. 628.

2 Beulaygue, Einfluss der Dunkelheit auf die Entwicklung der Blüten. Biedermann's Centralbl. 1902, p. 102.

3 Kraus, Über die Ursachen der Formveränderungen etiolierender Pflanzen. Pringsheim's Jahrb. f. wiss. Bot., Vol. VII, p. 209.

4 Koch, Ludwig, Abnorme Änderungen wachsender Pflanzenorgane durch Beschattung.

5 Gronemeyer in Agronom. Zeit. 1867, No. 34.

thus confirmed. The weakness of the stalks, which conditions the falling over in lodging is found actually in the lower stem members and the second internode (reckoned from the base of the stalk) is the one usually bent over.

To be sure, the first, lowest stem member is also weak, but, as a rule, it is too short to bend over; on the other hand, the second is the most elongated and the least thickened. The cells of this internode in lodged grain show a considerable over-elongation and scanty thickening in proportion to the corresponding cells of the normal stem. This deficient thickening is especially noticeable in those cells which, in the blade, fill the space between the outer membrane and the vascular bundle sheath, and actually conditions the firmness of the stalk.

Lodging of grain, therefore, is produced when the lower internodes of closely planted grain are insufficiently lighted. Too great shading also acts disadvantageously in the very early developmental stages of the plant by the over-elongation of the cells and the scanty thickening of the walls, which, as said above, takes place usually in the second internode from the bottom. This bad condition will occur more strongly in the places in the internodes where the leaf sheath surrounds the stalk most closely. This takes place near the base of the stem and the phenomena of etiolation are found most clearly and intensively here.

Formerly a lack of silicic acid was assumed as one reason for the lodging of grain. This may now be explained as erroneous, since it has been shown by water cultures of grain plants, that minimal amounts of silicic acid are sufficient to produce a normal plant and since analyses of lodged grain, compared with grain which had not lodged, have shown but little difference in silicic acid content. In normal plants also, as Pierre has shown for wheat and Arendt for oats, the lowest internodes of the stalk are the poorest in silicic acid, of which the greatest quantity in any case is found in the leaves. These can be 7 to 18 times as rich in silicic acid as the lower stem members.

Connected with the lack of light is the second point, given as a cause for lodging, namely, that the disease may be traced to an excessive supply of nitrogen in the soil. At any rate, this is one cause inasmuch as a too luxuriant development of the leaf apparatus is thus produced, essentially increasing the shading. Such a cause is given, however, by every circumstance which conditions a too thick stand from the seed, i. e., for example, too abundant seeding, too abundant water supply, etc.

Experiments made by Ritthausen and Pott[1] show the change in the maturing of fruit due to different nitrogen fertilizers and the tendency of the plant to lodge. While the grains of summer wheat are well matured with an abundant supply of nitrogen but remain small and glassy like the seed, the grains from plots not fertilized with nitrogen, lodge after less heavy rainstorms. Kreusler and Kern confirmed the above statements[2]. We may

[1] Landwirtsch. Versuchsstationen 1873, p. 384.
[2] Centralbl. f. Agrikulturchemie 1876, I, p. 401.

have in pure phosphoric acid fertilization a means of decreasing the dangers of a too large supply of nitrogen. At least, the results obtained by the above-named authors with wheat and barley showed that a fertilization with phosphoric acid alone (Baker guano with 18.97 per cent. soluble P_2O_5) resulted in a reduction of the nitrogen content of the grain.

But, aside from the composition of the grain, which is changed by an increased nitrogen supply, the whole amount of the harvest must be taken into consideration, which had suffered not a little from a too luxuriant and, therefore, too thick and dark a growth of the plant. Experiments based mostly on the conditions occurring in practice, since they show the influence of shading from the sides, have been cited by Fittbogen[1]. Under otherwise perfectly similar nutritive conditions, he shaded barley plants by means of a cylinder of rye stalks, fastened side by side and placed around the barley plants, and raised it in proportion to the growth in height of the experimental plant, which was constantly illuminated at the tip. The plants, therefore, had light for production but still in insufficient amounts. On this account, they produced only about two-thirds as much dry substance as plants illuminated on all sides, in spite of the 4 to 6 weeks longer growth which were needed for complete ripening. The dry substance, however, was also distributed much less favorably in the different harvest products. While, with a normal illumination, 47 per cent. of the dry substance in summer barley, as a whole, was found in the grain, and 53 per cent. in the straw and chaff, from shaded plants, only 39 per cent. of grain was harvested for 61 per cent. of straw and chaff, and the kernels were also poorer in quality. In regard to the water used, it was found that plants shaded on the sides, in spite of the at least 6 weeks longer growing time, had used only one-tenth more water in the hottest months (July and August). Therefore, in the same unit of time *they absolutely transpired considerably less* than the normally illuminated specimens, corresponding to the lesser production of dry substances. On the other hand, the plant will have evaporated relatively a great deal of water for we find, in shaded plants, that more than 500 g. of water were used per gram of dry substance, while normally lighted specimens have respired only something over 300 g. for the same amount of dry substance. Therefore, we find, in this vegetative factor, the same effect on transpiration as in others (soil solutions, carbon dioxid content in the air, etc.) *A supply of one vegetative factor kept below the optimum, increases* the relative use of water per gram dry substance produced.

The loss due to lodging will be decreased in many cases by the fact that grain possesses the ability to right itself. The process of righting consists in the ability of the nodes to show phenomena of growth at a time when the internodes have already lignified. According to de Vries' explanation[2], a new formation of osmotically effective substances takes place in

[1] Vortrag aus dem Klub der Landwirte am 14. Dez. 1875.

[2] De Vries, Über die Aufrichtung des gelagerten Getreides. Landwirtschaftl. Jahrbücher von Thiel. IX, 1880, Part 3.

the parenchyma cells of the under half of the node, which carries out the bending, under the force of gravity, because the stalk with its node, is bent toward the horizontal. These parenchyma cells attract water.

However, supported by the investigations of G. Kraus[1], we would like to assume that no considerable formation of osmotically effective substances (acids) takes place, but rather a longer retention of such substances on the convex side, as a result of a decreased oxidation of the organic acids. At least Kraus proves that as much acid is present on the convex as on the concave side in the occurrence of geotrophic and heliotrophic bending.

The only actually successful precaution lies in thinner seeding, the quantity of which must be modified according to the consistency of the soil. On sandy soils the seeding must be thicker than on loamy soils, and thicker with a poorer fertilization than with an abundant supply of nitrogen. Planting with the drill is found to be the most useful because the best distributed stand of plants is obtained thereby.

If, however, the seeding has already taken place and a close stand, luxurious development, and moist weather give rise to a fear of a subsequent lodging, the attempt should be made to remove a part of the leaf apparatus by strong harrowing, rolling, or prudent mowing and uprooting, in order to provide a sufficient access of light.

In regard to cultural regulations, we must refer to the recently published, very thorough work of C. Kraus[2], based on experimental studies, because the precautionary regulations, according to the different causes of lodging here mentioned, must also differ greatly. On general principles, it is not only a question of growing strong plants as resistant as possible to disturbances in equilibrium, but also to take pains that the plants, mechanically well developed above and below the soil, find the indispensable support within the soil of a properly developed root system. *The task of breeding* now follows these two directions. Even the weather at the time of seeding acts determinatively for the position of nodes, regulating essentially the anchorage of the plant in the soil. According to Schellenberg[3], the node lies higher if the seed develops in cloudy weather. It is, therefore, more advantageous (even for winter grain) when the seeds sprout in clear weather.

In weak stemmed plants, inclined to lodge, there occurs also at times a decay of the parts entirely removed from the light, which causes considerable loss in the *lodging of fodder peas.* The sowing of some horsetooth maise with these is recommended as a precaution. The peas can climb up the stems of the maise and its leaves also furnish good fodder.

The sowing of gold of pleasure (*Camelina sativa*) possibly 6 liters per hectare, is also recommended to prevent the lodging of peas, sweet peas, etc. This plant, which is perfectly hardy, ripens about the same time as

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1 Sitzungber. d. naturf. Ges. zu Halle 1880; cit. Bot. Centralbl. 1882, I, p. 107.
2 Kraus, C., Die Lagerung der'Getreide. Stuttgart 1908, Eugen Ulmer.
3 Schellenberg, H. C., Untersuchungen über die Lage des Bestockungsknotens beim Getreide. Forsch. auf d. Gebiete d. Landwirtsch. Frauenfeld 1902.

peas and the kernels may be easily separated from the peas by sifting, while the grain, generally grown with peas (summer rye and oats), is sifted out with much more trouble and exhausts the soil more for the following winter crop.

Here also, as in grain, breeders are now directing their attention to resistance to lodging. The Bulletins[1] published by the German Agricultural Society have proved to be most advantageous in this direction. They contain the latest results of cultural experiments with the different varieties of our cultivated plants.

Lack of Light as Predisposition to Disease.

When it comes to the attacks of parasites, the mechanical resistance of the membranes of etiolated plants will be less. However, the atmospheric influences become weaker and their fluctuations, reaching directly the cytoplasmatic cell body, can disturb its functions even if the etiolated plant should work in the same way and with the same energy as one which has sufficient light.

The last is, however, by no means the case.

The first indication of a change in function is found in the moving of the chlorophyll grains toward the side walls, in the dark. At the same time another significant change begins, viz., the *closing of the stomata.* According to Schwendener[2] this phenomenon, already observed in complete darkness, also sets in with a sudden decrease in the intensity of illumination. It is possibly not a result of the lowering of the temperature connected with the decrease of light, for an increase in temperature within the usual fluctuations causes no opening of this apparatus. Connected with this also is the fact that a longer suppression, or reduction of the exchange of gases, can bring about changes in the cell contents, due to a lack of oxygen, that is, for example, a tendency to the formation of alcohol. These disturbances will occur so much the more easily, the more intense the capacity for growth and the greater the need for ventilation. Therefore, very young organs will feel this, while old leaves, grown for many years, with a lesser need of light, endure longer limitation in the exchange of gases. Nature indicates this also by the wall thickening of the guard cells, increased with advancing age, which, according to Schwendener, is so strong at times that no further opening of the stomata can be possible.

In regard to lessened transpiration, I found in young seedlings of Phaseolus, dependent upon their cotyledons, such a difference between etiolated and normal plants that the former, on an average, transpired in the same period of time, 0.21 g. per sq. cm. leaf surface; the latter, 0.29 g.[3] The production of dry substance in a plant, under otherwise equal condi-

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1 Mittel. der Saatzuchtstelle über wichtige Sortenversuche 1905-1907 usw.

2 Schwendener, Über Bau und Mechanik der Spaltöffnungen. Monatsber. d. Kgl. Akad. d. Wiss. zu Berlin, July, 1881; cit. Bot. Zeit. 1882, p. 234.

3 Sorauer, Studien über Verdunstung. Aus Wollny's "Forschungen auf dem Gebiete der Agrikulturphysik." Vol. I, Part 4-5, p. 116.

tions, parallels the transpiration. Investigation showed that not only the absolute production of the young plants was essentially more energetic in the light, but that also a square centimeter of leaf surface developed a greater amount of substances. A weakening of the light, by means of colored media, through which the rays must pass, acts similarly to the removal of light by placing it in the dark. In yellow light, assimilation and transpiration are more energetic than in blue light; at least the majority of experiments favor this[1].

The energy of production of plants and also the mode change with the decrease of light and this change is expressed, not only in the *metamorphic*, but also in the *metabolic structure*.

The well-known experiment of covering leaves in the light with a stencil pattern, which leaves free some rather larger surface figures, removing the green from these leaves after some days by means of alcohol, and then wetting them with iodine solution, is a simple illustration of the action of light. All parts of the leaf, which have been exposed to the light, look blue because of the action on the starch which had been formed in the light. This experiment is of interest inasmuch as it shows how locally limited the action of light is. Only the part which had been illuminated formed starch and no starch passed over into the darkened, adjacent part. The most important thing, according to this, is that the green parts of the plant must themselves work over their constructive materials if they should continue to live.

It has been mentioned already that the mobilized reserve substances pass into the young, entirely darkened shoots a certain distance from the tubers and seeds. If the distance is too great, however, the shoots finally die from starvation. They breathe up more respiratory material than they receive in the form of sugar, etc. Some of Müller-Thurgau's[2] experiments show, for example, that the starch, when dissolved, passes over into sugar, which is used up partly for construction and partly in respiration. Grape leaves, which contain 2 per cent. sugar and as much starch, were cut off and their petioles put in water. The container was set in a room at zero degrees. Nine days later all trace of the starch had disappeared. Since the respiration of the grapevine, however, at zero degrees is very slight, the sugar, produced by the solution of the starch in the dark, cannot have been used up in respiration and must, accordingly, have accumulated in the leaf. As a fact, investigation shows 4 per cent. sugar in the leaves.

Thus, placing in the dark will promote the formation of sugar in the organs as against the formation of starch. If, as is frequently the case in growing plants out of doors, an actual temperature decrease takes place with the decrease in light, it means a *blocking of sugar* in the assimilatory tissues.

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[1] Compare Hellriegel, Beiträge, p. 378. Nobbe, Versuchsstationen XXVI, p. 354. Flahault, Bot. Centralbl. 1880, p. 932. Dehérain, Bot. Zeit. 1873, p. 494.

[2] Müller-Thurgau, Über den Einfluss der Belaubung auf das Reifen der Trauben. Weinbaukongress zu Dürkheim a. d. H. 1882.

Anyone who has cultivated fungi in nutrient solutions knows, however, how favorably a supply of sugar acts on the development of many parasitic fungi.

Cloudy, cool days, therefore, not only weaken the assimilation in the green parts of the plants but, at the same time, by *reducing the respiratory processes, bring about an accumulation of sugar in the leaf cells and, therefore, make possible the production of a more favorable substratum for parasites.*

The *acid content* of the various plant parts is also very different in the dark from that found when the organ is favorably illuminated.

The observation, that many plants (Crassulaceae) taste sour at night[1] but not noticeably so during the day[2] is very odd. In etiolated plants, Wiesner could recognize an abundance of organic acids[3] in the leaves of many monocotyledons, and later De Vries observed[4] that the stems of etiolated dicotyledons are strongly acid. When illuminated, the rich sugar content disappears. This has been, at least, especially proved for the Crassulaceae, in which, in the night, De Vries could determine a rich acid formation only when the plants had been abundantly lighted during the day, but, if the supply of light was limited to a few hours, the acid content in the night was correspondingly less.

An increase of warmth increases also the decomposition of the acids in the dark. Cooler nights lead to the storage of acid.

De Vries has proved this directly by experiments[5]. It is evident, however, from the fact that the loss of acid becomes less with each successive day of shading, that the disappearance of the acids is connected with the supply of material for the formation of acid which has been worked over in the light.

Plants, therefore, constantly produce acids and the more energetically the stronger growing the organs are. With light, the acids are oxidized as fast as they are produced; in the dark, they are stored up. On this account, etiolated plants are relatively rich in acids. The suppression of the inflorescences increases the content of free acids in the leaf. The acid content in the roots is also subjected to great fluctuations and, according to Charabot[6], in plants cultivated in the shade it is, in fact, larger than in the leaves. In general, this acid content is greater in etiolated plants.

This accumulation of acids in and of itself can offer those fungi, which decompose acids, the possibility of colonization and luxuriant development;

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1 Heyne und Link in Jahrbuch der Gewächskunde von Sprengel, Schrader und Link, 1819, p. 70-73.

2 Ad. Mayer, Über Sauerstoffausscheidung usw. Verhandl. d. Heidelberger naturf. Gesellsch. 4-8, 1875. Landwirtsch. Versuchsstat. 1875, Vol. XVIII, p. 410, Vol. XXI, p. 277.

3 Wiesner, Sitzungsber. d. K. K. Akad. d. Wissensch. I, April, 1874, Vol. 69; cit. Bot. Zeit. 1874, p. 116.

4 De Vries, Über die Bedeutung der Pflanzensäuren für den Turgor der Zellen. Bot. Zeit. 1878, p. 852. Über die periodische Säurebildung der Fettpflanzen. Bot. Zeit. 1884, Nos. 22 and 23.

5 Bot. Zeit. 1884, p. 340.

6 Charabot, E., et Herbert, A., Recherches sur l'acidité végétale. Compt. rend. 1904, CXXXVIII, p. 1714.

however, an excessive increase of turgidity in the tissue can be ascribed to this since, according to De Vries, it is especially the plant acids which condition the turgidity of the cells.

The experiments of Viala and Pacottet[1] on *black rot* (*Guignardia Bidwellii*) show how very determinative this acid content can often be. Infection experiments in young berries are successful only so long as the acid content exceeds the sugar content. Not only the content in organic acids is increased but also the indifferent ash material is changed by the changed absorption of nutrition. This is shown by André's experiments[2] He tried to excite etiolated plants to unusual activity by increasing the temperature (30 degrees), but found only an unusual increase in the absorption of silicic acid, with an exclusion of other mineral elements.

The decomposition and counter building of the proteins in the plant cell[3] also stand in the closest connection with the above described processes of the formation and oxidation of the carbohydrates.

In the germination and sprouting of buds on branches, roots and tubers, we find products of the decomposition of proteins which are similar to those of artificial protein decomposition, i. e., asparagin, glutamin, leucin, tyrosin, occur in very large amounts. According to Borodin's investigations[4] these amido compounds occur more abundantly, the fewer the elements present which are free from nitrogen (especially the grape sugar) and which can be used for the breaking down of the proteins.

Since in etiolated plants, as well as in others grown in the light but in air free from carbon dioxid, the new production of carbohydrates is suppressed and since these are used up by day in respiration, an accumulation of asparagin will take place. Among the more recent observers, we will mention Zaleski (cf. next page) who found an increase of asparagin in seedlings of *Allium Cepa*. The above mentioned work by Schulze and Castoro[5] should be especially considered, from which it is seen that, for example, in etiolated seedlings of *Lupinus Albus* the content in protein substances decreases; that in aspargin constantly increases. Tyrosin and leucin decrease.

As a matter of fact, E. Schulze found more than half of the whole nitrogen content in 20 day old etiolated lupin seedlings in the form of asparagin[6]. If now the nitrogen free part of the protein molecule is used up in respiration and no new elements, lacking nitrogen, are present to reconstruct normal protein in the protoplasm, the cell will undergo the most

1 Viala, P., et Pacottet, P., Sur le développement du Black Rot. Compt. rend. 1904. CXXXIX, p. 152.

2 André, G., Wirkung der Temperatur auf die Absorption der Mineralstoffe bei etiolierten Pflanzen. Compt. rend. 1902; cit. Biedermann's Centralbl, f. Agrikulturchemie 1903, Part 2.

3 Pfeffer in Jahrb. f. wissensch. Bot. 1872, Vol. 8, p. 548. Tagebl. d. Naturf. Vers. z. Wiesbaden.

4 Bot. Zeit. 1878, p. 802 ff.

5 Schulze, E., und Castoro, N., Beiträge zur Kenntnis der Zusammensetzung u. des Stoffwechsels der Keimpflanzen; cit. Bot. Centralbl. 1904, Vol. XCVI, p. 540.

6 Schulze, E., Über den Eiweissumsatz im Pflanzenorganismus. Landwirtsch. Jahrbücher. 1880, p. 1-60.

extensive disturbances. It is probable that a further decomposition will introduce phenomena of decay which produce the best nutrient substrata for parasites and saphrophytes. The asparagin is worked up well by the fungi in the presence of sugar. Vogel[1] found in the germination of moistened cress seed that hydrogen sulfid was produced in the dark, while, in check experiments, in lighted places, the lead paper showed practically no change.

A different process may prevail in the leaf parenchyma from that in the leaf veins. In young Dahlia plants Borodin[2] proved the presence of saltpetre in the veins and in the petioles, but large amounts of tyrosin and no saltpetre in the leaf parenchyma. Here the tyrosin may well be no analytic product but rather a synthetic one; for if the young shoots of dahlias become etiolated, no tyrosin is formed, but asparagin, which does not appear when the plants are grown in the light.

At times, at any rate, an increase in proteins is found in the dark but it is then caused by the very abundant carbohydrates at the plant's disposal in the stores of reserve substances, as Iwanoff[3] has shown, for example, for *Allium Cepa*. If carbohydrates are present, the leaves, even in the dark, can change the nitrate nitrogen into protein nitrogen, as Zaleski[4] found in the leaves of Helianthus, which had been placed in a nutrient solution containing nitrates and sugar.

We have stated here simply a series of facts which show the natural changes in the plant body due to a lack of light. These explain sufficiently the decreased power of resistance of the shaded plant parts through atmospheric influence, as well as parasitic attacks.

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1 Vogel, Ein auffälliger Unterschied zwischen Keimen am Tageslicht und im Dunkeln; cit. Bot. Jahresber. 1877, p. 675.

2 Sitzungsber. d. Bot. Sekt Petersburg. Naturf. Ges. 1881; cit. Botan. Zeit. 1882; p. 589.

3 Iwanoff, M., Versuche über die Frage, ob in den Pflanzen bei Lichtabschluss Eiweissstoffe sich bilden. Landw. Versuchsstationen 1901, p. 78.

4 Zaleski, W., Die Bedingungen der Eiweissbildung in den Pflanzen. Charkow 1900 (Russian); cit. Bot. Centralbl. 1901, Vol. 87, p. 277.

CHAPTER XIV.

EXCESS OF LIGHT.

According to the discoveries, already made in great numbers, on the influence of heat on the different vegetable processes, it must be supposed, from the outset, that not only does a minimal limit exist for the action of light, but that also a special degree of illumination exists in each plant *for each process and for each combination of the vegetative factors,* which can be termed the optimum. The exceeding of this degree introduces a retrogression in production. In fact, the observation has already been made for a number of plants that, if the light is increased above a certain amount, the assimilation, perceptible in the elimination of oxygen, does not increase, but remains stationary[1], or indeed may decrease[2]. A normal carbon dioxid content in the air is presupposed in this, for even when the air contains too large an amount of this element, the elimination of oxygen retrogresses, as has been proved already by Boussingault and, later, by Pfeffer[3]. An optimum illumination may be seen in the appearance of the plant since this loses its deeper green color, with a considerable increase in the intensity of light above the optimum; then it assumes a yellowish color.

That the dark green leaves of camellias show a *yellowed condition,* when moved from the conservatory into sunny places out of doors, is well known. The camellia is a Japanese plant which grows under trees. It is content with small quantities of light and, with the strong rays of our summer sun, soon loses more chlorophyll through oxidation than can be formed by the process of reduction. The breaking down of the chlorophyll by the taking up of oxygen (taking place also in the dark in the presence of bodies which easily take oxygen from the air and form ozone, Turpentine oil) is known to be connected with different groups of rays. According to Wiesner, the yellow rays, and the green and orange ones on both sides of them, show the greatest energy in the breaking down of the chlorophyll in the light.

Another example of yellow leaves with a high intensity of light is offered by some varieties of coleus with yellow variegated leaves. These

1 Reinke, L., Untersuchungen über die Einwirkungen des Lichtes auf die Sauerstoffausscheidung der Pflanzen. Bot. Zeit. 1883, No. 42 ff.

2 Famintzin, Effet de l'intensité de la lumière, etc.; cit. Bot. Centralbl. 1880, p. 1460.

3 Pfeffer, Arbeiten d. Bot. Instituts zu Würzburg, ed. by Sachs, Part 1.

produce leaves which at first unfold as green leaves and later, when they become old, become light yellow in places. In the same way, many yellow garden varieties of woody plants only become a bright yellow with strong insolation; in the shade they remain green.

Ewart[1] observed in tropical plants a complete bleaching of the chlorophyll grains as a result of an excess of light. If the light stimulus increases above the specific optimum, the optimal and maximal development of gases at first continues for a short time, but then follows a condition of exhaustion[2]. If this excessive stimulation does not last too long, the plant can recover its normal activity. This over-stimulation can also occur under our normal light conditions, if the plant, by nature, belongs among shade plants. Weiss[3] cites a fine example of this in *Polypodium vulgare,* a decided shade plant, as contrasted with *Oenothera biennis* which is distinctly a sun plant. With a favorable temperature, the latter produced about three times as much carbon dioxid in direct sunlight as in diffuse light; while the former assimilated more energetically in diffuse light. Diffuse daylight can, in fact, act to arrest the growth of roots which are accustomed to the dark, as Kny found in lupines, cow beans, and water cress[4]. In this, he observed in lupines usually a decrease of growth in thickness and a retarding of the development of the central cylinder, if the growth in length increased.

The works of Dixon, Dixon and Wigham, Joseph and Prowazek, Max Koernicke and Hans Molisch[5] prove a very decided arrestment of growth from the use of Röntgen and radium rays.

An abnormal thickening and a wrinkled surface were observed in pea roots, which could be traced, apparently, to differences in internal tension. Contractions are produced by the increase in the radial diameter of the cells of the inner bark parenchyma, together with a shortening of the longitudinal diameter. It was found in other experiments with vetches and horse beans that the roots turned brown and their growth was arrested. But after 8 to 10 days they grew further, after having thrown off the outermost tips in the form of brown caps, and formed new root tips directly behind these. Normal lateral roots were produced immediately. The arrest of growth is less in organs containing chlorophyll. In seedlings a cessation in the growth in length has been observed but no dying back. The leaves became somewhat smaller than in normal specimens. Dixon[6] could not

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[1] Ewart, A. J., The effects of tropical insolation; cit. Just's Jahresber. 1899, I, p. 87.

[2] Pantanelli, Enrico, Abhängigkeit der Sauerstoffausscheidung belichteter Pflanzen von äusseren Faktoren. Jahrb. f. wiss. Bot. 1903, Vol. XXXIV, p. 167.

[3] Weiss, Fr., Sur le rapport entre l'intensité lumineuse et l'énergie assimilatrice chez les plantes appartenant à des types biologiques différents. Compt. rend. Paris CXXXVII, 1903, p. 801.

[4] Kny, L., Über den Einfluss des Lichtes auf das Wachstum der Bodenwurzeln. Jahrb. f. wiss. Bot. 1902, Vol. 28, p. 421.

[5] Seckt, Hans. Die Wirkung der Röntgen- und Radiumstrahlen auf die Pflanze. Sammelreferat Naturwiss. Wochenschrift. 1906, No. 24.

[6] Dixon, Henry, Radium and plants. Nature, London LXIX; cit. Just's Bot. Jahresber. 1903, II, p. 567.

find heliotropic curvature in young cress seedlings at a distance of one centimeter from a glass tube containing 5 g. of radium bromid.

In bright sunlight, we find that parts of the plant often not only become yellow but even turn brown and die[1]. That this dying is a specific light action and not a result of too great an increase in temperature is proved by the fact that the chlorophyll remains unchanged[2] in temperatures varying from 30 degrees below zero to 100 degrees above zero and, on the other hand, that the destruction takes place with rays of shorter wave length which influences most of all the processes of growth and protoplasmic movement.

The rays of a concentrated sun image, which have passed through ammoniacal copper oxid often cause death after a few minutes, while the same amount of light, after passing through a solution of iodine in carbon disulphid (which lets only the outermost red rays pass through) scarcely causes any destruction, or only a very tardy one[3]. In this red light, however, an extensive warming takes place, but not in the blue light.

Among the phenomena arising from an excess of light belongs also the production of *shadow pictures,* i. e., intensive green pictures of overshadowing organs on a strongly lighted leaf surface. No destruction of the chlorophyll apparatus necessarily takes place here, only a change in the position of the chloroplasts is produced.

Observations, made by Böhm, Famintzin, Borodin, Stahl and Frank, proved that, in sunlight too high for the special need of the plants, the chlorophyll grains begin to move from the cell walls, parallel to the upper surface of the leaf, towards the walls at right angles to them. The chloroplasts pass from the ***epistrophe*** to the ***apostrophe*** and thereby bring about the lighter color of the too strongly lighted part.

A further observation which can be made easily is the appearance of a *red color* with too strong lighting in the green leaves of plants which turn red in the autumn, as, for example, when the under sides of sweet cherry leaves are turned uppermost. In the same way, a decided brownish red color may be found in many plants, especially in those with fleshy leaves, when brought in spring from the shaded conservatories into an open, sunny place. Molisch[4] has investigated such cases. He proved in Aloe and Selaginella that anthocyanin is not formed in the cells but that the chloroplasts themselves turn red and become green again when put in the dark. In some varieties of Selaginella, red or brownish red chloroplasts were observed, colored by carotin, especially above a place where the stem had broken.

The process most important agriculturally and most significant hygienically, however, consists in the destructive action of the sunlight on

1 Böhm, Versuchsstationen 1877, p. 463.
2 Wiesner, Die naturlichen Einrichtungen zum Schutze des Chlorophylls. Festschrift; cit. Bot. Jahresber. 1876, p. 728.
3 Pringsheim, Jahrb. f. wiss. Bot. 1879, Vol. 12, p. 336.
4 Molisch, H., Über vorübergehende Rotfärbung der Chlorophyllkörner in Laubblättern. B. der Deutsch. Bot. Ges. 1902, XX, p. 442.

pathogenic fungi and especially on bacteria. Pfeffer[1] says, "It seems that all pathogenic bacteria are killed by a sufficient exposure to sunlight."

That artificial light acts in the same way as sunlight is proved, for example, by the experiments made by Dixon and Wigham[2] with radium rays. Cultures made with *Bacillus pyocyaneus, B. typhosus, B. prodigiosus* and *B. anthracis* showed that the β rays of radium bromid called forth a perceptible arrest of growth. After 5 mg. of radium bromid had acted 4 days on the bacteria, at a distance of 4.5 mm., their growth, at least, was stopped, if they were not all killed.

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1 Pflanzenphysiologie, 2d ed., Part II, p. 819.

2 Dixon, Henry H., and Wigham, J., Action of Radium on Bacteria. Nature, London LXIX; cit. Just's Jahresber. 1903, II, p. 567.

SECTION III.

ENZYMATIC DISEASES.

CHAPTER XV.

DISPLACEMENT OF ENZYMATIC FUNCTIONS.

General Discussion.

Present investigations tend to the theory of perceiving, in the majority of metabolic processes, the action of enzymes. We would like to divide these enzymes into two groups, according to their activity, which may be called constructive and destructive. In the process of formation of the vegetative organism, we observe in germination, i. e., in the preparation for the vegetative development, a prevalence of the destructive activity since the reserve substances are dissolved and carried over into usually instable groups of substances, capable of being transported. The activity of the vegetative apparatus leads gradually to the precipitation of reserve substances and we term this activity constructive. Its final goal may be recognized in the maturation of the seed.

From this may be perceived an antagonism in the occurrence of the most important material groups, which antagonism may be determined by the fact that, in abundant deposition of starch, the sugar content, as well as the amount of tannin and of organic acids, decreases. If, on the other hand, sugar, tannin and acids are abundantly present, the precipitation of starch remains small. If the amount of starch is large, the formation of the proteids in the cell from asparagin or other nitrogenous compounds is abundant. In the preponderance of sugar and acids, the nitrogenous compounds remain in an instable form. I would like to contrast this condition of the plant parts as *"immature,"* with the *"mature"* condition which is distinguished by an abundance of reserve materials.

The different factors of growth that influence constantly the plant body sometimes let one group of enzymes prevail, sometimes another. It is not necessary that the enzymes be destroyed. Their action need only be

temporarily arrested. Pozzi-Escot[1] furnishes an example of this when discussing the Philothion. *"Reductases,"* he thinks, which are identical with Loew's *catalase,* "are distributed everywhere like oxydases, and act antagonistically" . . . De Rey-Pailhade has proved that reductases are quickly destroyed by an oxydase in the presence of free oxygen, and, conversely, Pozzi-Escot proves that, under certain circumstances, the action of an oxydase can be "paralyzed," when the reductase is present in great excess. Thus, in temporary fluctuations in the cell contents, a reductase can, for the moment, make the oxydase ineffective, and conversely. Pozzi-Escot perceives the most important rôle of the reductases to be their action on H_2 O_2 in the processes of respiration as well as in photo-synthesis.

Antiferments occur in other cases, as Czapek[2], for example, has demonstrated. He found an arrestment in the further oxidation of the homogentisin acid, originating from tyrosin, in organs stimulated geotropically or heliotropically by the presence of an antiferment.

In general, we perceive from the results of cultivation and some experimental investigations, that light and heat favor catabolism, i. e., disposition of groups of solid reserve material, while darkness and cold either maintain, or cause an increase in the amount of colloidal food materials.

Under normal climatic conditions, the time at which prevailing conditions in the cell contents exhibit the conditions characteristic of the destructive activity, lies actually in the colder seasons of the year. We find processes of germination especially in autumn and spring, but, on the other hand, constructive activity, i. e., the deposition of reserve materials, in the summer.

The necessary regular succession of these periods depends, however, not only on the weather but also on all the nutritive factors, as, for example, the supply of water, the amount and constitution of the nutrients, and, besides this, on differences in cultivation, viz., pruning, etc. A number of diseases offer examples for the last point, i. e., when the organism is compelled, by the sudden removal of considerable amounts of the plant body (branches and leaves), to mobilize again the stored material at a time when the period of storing should prevail and, thereby, to return to the vegetative period for the formation of new shoots. In regard to the supply of food we find, for example, that excessive amounts of nitrogen postpone the period of storing up reserve materials since growth is continued beyond the normal size.

Thus, the enzymatic work is postponed; the mobilizing enzymes now prevail and the plant, with organs in active growth, enters upon a period of weather which, in the normal course of events, demands mature plant parts, rich in reserve materials. It becomes, therefore, susceptible to parasitic and non-parasitic attacks.

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[1] Pozzi-Escot, E., The Reducing Enzymes. American Chem. Journ., Vol. XXIX, 1903, p. 517; cit. Bot. Centralbl. 1904, No. 49.

[2] Czapek, F., Antifermente im Pflanzenorganismus. Ber. d. Deutsch. Bot. Ges. 1903, Vol. XXI, p. 229.

It is, however, not only the momentary displacement of the enzymatic functions which can act disadvantageously on the organism, but the number of subsequent phenomena must necessarily be connected with it, which will manifest themselves only in the next generation. If, for example, we keep in view the lengthening of the period of growth, induced, as experience shows, by an excess of nitrogen, the immediate result is that the production of seed, which normally occurs at the period of the greatest amount of heat and light, is carried over into a cooler time when the light is poor. The seed thus produced, therefore, does not have sufficient time and proper climatic conditions to carry on all the processes necessary for the formation of reserve materials. The seed is harvested in a condition in which the mobilizing enzymes are still considerably active and it, therefore, is susceptible to attacks by parasites affecting the fully matured seed. It has been proved experimentally that immature seed is destroyed more quickly by moulds. Even if the immature seed is not destroyed, and develops the following season, the plant thus produced will necessarily be influenced in its first growth by the greater amount of water content in the seed and the lesser amount of reserve materials. In this connection the following generation is the product of the preceding one, and, therefore, will reproduce by inheritance conditions of weakness.

Everything that is true of the seed, must *also* hold good for all other permanent organs. The bud and the maturation of the branch are, in the same way, the product of the preceding period of growth and the manner of their further development depends primarily on the degree of maturity to which they attained in the previous year.

Displacements of the enzymatic functions, therefore, are continued from one period of growth to another and the diseases, subsequently described, are examples of the inheritance of physiological disturbances.

Albinism (Variegation).

The phenomenon, sought by gardeners and propagated by grafting (which may, in fact, be carried over to the stock), manifests itself in the whitish appearance of places which sometimes have a circular form in the diachyma (mesophyll), sometimes appear as wedge-shaped stripes between the ribs, and sometimes as connected zones along the edge of the leaf. The intensity of the white coloration varies. The most diverse transitions from the purest white to quince yellow are found, which in many plants give still further color shades because of the occurrence of reddish tones. In this way is produced the phenomenon called variegation.

A very well-known example of this white spotted condition is found in the ribbon grass of our gardens (*Phalaris arundinacea* L., *Phalaris picta* L.), in which the white parts occur alternately as stripes between the veins. A toy species of the ash leafed maple (*Acer Negundo* L.) is still more striking. At times this shows perfectly white foliage. The family of the Aroideae might be named as examples of the occurrence of variegation as

well as of white coloring. Among these, the calla, frequently cultivated in the house (*Zantedeschia aethiopica*), shows leaves which often are as pure white as the funnel-shaped blossom sheath. The bright colored calladia, greenhouse favorites, are related to the Zantedeschia. Among them a few are only specked with white, others have white and red spots, and many finally only red spots.

The white spotted condition of the flowers and the more rare albinism of fruit are difficult to distinguish. Of the latter, Dufour[1] has described interesting cases in grapes.

There prevails, especially in practical circles, an earnest hesitation in accepting the theory which ascribes the white variegated leaves to the phenomena of disease. Yet, we believe that this opinion must be defended. If we investigate a considerable number of plants with variegated leaves, we find all gradations in the cells from the normal chloroplasts to the entire disappearance of the chloroplastids. The parts of the plants which appear yellowish often have chloroplasts which appear as yellow, sponge-like balls or discs in the cells; the purer white the plants are, the fewer are the even colorless chlorophyll bodies; and the more the cytoplasm assumes the appearance of a soft, uniform wall lining. The intercellular spaces contain more air and at times are larger.

The assimilation of carbon dioxid also ceases with the disappearance of the chloroplasts. Cloëz[2] and later Engelmann[3] found that the leaves assimilate carbon dioxid only in proportion to their chlorophyll content. The different gradations in the yellow variegation arise from lesser quantities of the same chlorophylline and zanthophyll, than occur in the normal green leaves[4] and their assimilatory activity is in accordance with this.

In pure white leaves the chlorophyll does not form and the chloroplasts are poorly developed. In the yellow forms, chloroplasts are found at least in the bud and often later but the degree of degeneration of the chloroplasts depends on their proximity to the pure white zone. The analyses given by Church[5] serve as a good confirmation of this. He used white variegated forms of maple (*Acer Negundo*), Ivy (*Hedera Helix*) and Holly (*Ilex aquifolium*):

	Acer		Ilex		Hedera	
They contained	white leaved per cent.	green leaved per cent.	white leaved per cent.	green leaved per cent.	white leaved per cent.	green leaved per cent.
Water	82.83	72.70	74.14	62.83	78.88	66.13
Organic substances	15.15	24.22	23.66	35.41	18.74	31.63
Ash	2.02	3.08	2.20	2.47	2.38	2.24

1 Defour, J., Panachierte Trauben. Extr. Chronique agric. du canton de Vaud; cit. Zeitschr. f. Pflanzenkrankh. 1904, p. 286.
2 Compt. rend. LVII, p. 834.
3 Engelmann, Farbe und Assimilation, Bot. Zeit. 1883, Nos. 1 and 2.
4 Kränzlin, G., Anatomische und farbstoffanalytische Untersuchungen an panachierten Pflanzen. Inaug.-Diss. Berlin 1908.
5 Church, Variegated leaves. Gardeners' Chronicle 1877, II, p. 586.

The green leaves show, therefore, in contrast to the white spotted ones, considerably greater amounts of dry substances, while in the latter the ash constituents (as found universally where disturbances in nutrition make themselves felt) form a greater percentage of dry substance. The nitrogen content in the white leaves of the ivy and the holly was greater in proportion to the dry substance. This result is also explicable; for, if the chlorophyll apparatus, without doubt necessary for the production of starch grains and other carbohydrates, is only scantily present, the amount of dry substances is reduced and the absolutely smaller amount of substances containing nitrogen appears relatively increased. The fact that the substances soluble in alcohol and ether in the white leaves of ivy and holly amount to about half that in the green leaves likewise may not be considered surprising.

The percentages in the composition of the ash are very important. They are as follows:—

	Acer		Ilex		Hedera	
	white per cent.	green per cent.	white per cent.	green per cent.	white per cent.	green per cent.
Potash	45.05	12.61	35.30	16.22	47.20	17.91
Lime	10.89	39.93	21.50	34.43	12.92	48.55
Magnesia	3.95	4.75	3.23	2.43	1.11	1.04
Phosphoric acid...	14.57	8.80	9.51	7.29	10.68	3.87
Iron oxide	?	?	3.11	3.11	2.62	2.31

It is evident from these figures that organs without pigmentation approximate the condition of young green leaves and have, therefore, failed to develop in a normal manner. Griffon[1] has come to the conclusion that plants without pigmentation behave in general like etiolated ones, which we have also compared to arrested development. In the yellow transitional stages the results of variegation are very different. In *Abutilon Thompsoni* I found the cell content in many leaves still arranged as in perfectly green parts, i. e., provided with chloroplasts, their edges roundish angular, which were normally arranged against the walls but were a pale yellow, or colorless, and had a strongly granulated content. In other cells the substance of the chloroplasts was united into irregular granular balls which took on a blue color with iodine, glycerine, and in part also with sulfuric acid and which might be called carotin. Kohl[2] also found carotin (etiolin), in the investigation of golden yellow leaves, besides β-zanthophyll and phyllofuscin.

The difference in the thickness of the leaf, i. e., the noticeably lesser thickness of the pure white parts in contrast to the pure green parts, decreases the more the color tone varies from the pure white; i. e., the more yellow the places in the leaf become. Timpe[3] also calls attention to this

[1] Griffon, Ed., L'assimilation chlorophyllienne et la coloration des plantes. Annal. sc. nat. VIII, 1899; cit. Bot. Jahresber. 1899, I, p. 151.
[2] Kohl, F. G., Untersuchungen über das Carotin und seine physiologische Bedeutung in der Pflanze. Leipzig, Bornträger, 1902, IX.
[3] Timpe, H., Beiträge zur Kenntnis der Panachierung. Dissertat., Göttingen, 1900.

circumstance and lays emphasis on the fact that the slime cells are fewer in the non-pigmented parts of plants which bear the mucilage cells (Ulmus, Crataegus). On the other hand, the content of tannin in the white parts is usually proved to be greater. Starch is found rarely but, according to Timpe, in a sugar solution is often formed more abundantly by the non-pigmented places than by the green ones. Monocotyledons store up no starch in a sugar solution.

It is stated by other authors that the pure white places contain no starch since assimilation does not take place there. These apparent contradictions are explained by the transitional stages to a golden yellow color which, indeed, contain no chlorophyll but have zanthophyll and carotin and eliminate oxygen in the light (like etiolated leaves)*.

An interesting fact is that in many plants a lack of pigmentation may be communicated to the stock by grafting. Meyer[1] reported experiments of this kind with positive results as early as 1700-1710 with *Jasminum officinale.* "If a branch of Jasminum with variegated leaves is grafted on the healthy trunk of the same Jasminum, the other branches above and below the scion likewise bear variegated leaves." Later Lindemuth[2] and recently Baur[3] have studied the question especially. Baur has advanced the theory that the *yellow* forms may be considered to be sport varieties, or mutations, which in part persist in the seed. The pure white, however, should be distinguished from these as examples diseased by infection. At any rate, the infecting body may be no living creature, but an unknown material something, a *virus* which can increase in amount within the diseased plant. This virus can be a metabolic product of the diseased plant which is able to infect the young chloroplasts in such a way that they cannot develop to normal organs, but to malformations in which then the same virus is formed anew. However, it may be a metabolic product of the diseased plant which, in a certain sense, has the capacity for growth, i. e., can split off substances from other compounds identical with it, or can synthetically construct new substances of this kind[4].

This line of thought has already been expressed in a more precise form by Pantanelli[5], and later supplemented. He says[6], "the albinism is not an infectious disease, but a constitutional one, the first sign of which occurs as an abnormal accumulation of destructive and primarily oxidizing enzymes." "The substances, causing the destruction, spread through the leptome

* Kohl, loc. cit.

1 Meyen, F. J. F., Pflanzenpathologie, Berlin, 1841, p. 288.

2 Lindemuth Vegetative Bastarderzeugung durch Impfung. Landwirtschaftl. Jahrbücher 1878, Part 6. Gartenflora 1901, 1902, 1904.

3 Baur, Erwin, Zur Aetiologie der infektiösen Panachierung. Ber. d. Deutsch. Bot. Ges. 1904, Vol. XII, p. 453. Further statements on the infectious chlorosis of the Malvaceae and other similar phenomena in Ligustrum and Laburnum. Ber. d. Deutsch. Bot. Ges. 1906, Part 8, p. 416.

4 Baur, E., Über die infektiöse Chlorose der Malvaceen. Sitzungsber. d. Kgl. Preuss. Akad. d. Wiss. January 11th, 1906.

5 Pantanelli. E., Studii su l'albinismo nel regno vegetale. Malpighia. Vol. XV-XIX (1902-5).

6 Pantanelli, E., Über Albinismus in Pflanzenreich. Zeitschr. f. Pflanzenkrankheiten 1905, p. 1.

bundles, either because of an energetic influence due to adjacent and communicating protoplasts, or of a material transportation by means of sieve tubes and analogous elements throughout the entire body; they reach at last the developing petioles and then the main ribs of the leaves. Here they influence all the parenchyma cells with which they are connected clearly more energetically or because of a *poor nutritive provision and removal*." The transference of the phenomena from the scion to the stock, therefore, comes about if, in grafting, the leptome connection in the two component parts has been established.

This theory is based on experimental studies. It has been proved by chemical investigation that "the protoplasm and plastids are gradually attacked by abnormal formations of strongly destructive enzymes and digested by them." In some intensive cases of albinism no accumulations, however, of inorganic, or organic substances, or sugar, may be proved.

A determination made by Pantanelli on Ulmus leaves throws light on the behavior of the nitrogen compounds. He pulverized green and non-pigmented leaves with the necessary precaution and let the pulp stand 8 days in a cylinder. The original amount of water in the green leaves averaged 60.67 per cent., that in the non-pigmented leaves of the same tree, at the same time, 73.8 per cent.

The green leaves contained (in percentages of the dry weight).

	In the beginning	After 8 days
Nitrogen as a whole...........	3.355 per cent.	3.3250 per cent.
Proteid nitrogen	3.324 "	0.9212 "
Non-proteid nitrogen	0.031 "	2.4050 "

Non-pigmented leaves contained (in percentages of the dry weight):

	In the beginning	After 8 days
Nitrogen as a whole	2.681 per cent.	2.576 per cent.
Proteid nitrogen	2.274 "	0.604 "
Non-proteid nitrogen	0.407 "	1.972 "

Autolysis in the sap of the variegated leaves is, therefore, comparatively more extensive than in the green ones. The amount of nitrogen in non-pigmented organs is considerably less, but the percentage of non-proteid nitrogen compounds is greater. The richly abundant phosphoric acid must be present in some other combination since lecithin cannot be formed nor the chloroplast be developed. Also, according to Pantanelli's investigations, an enzyme which breaks up the starch seems to be present more abundantly in the variegated leaves than in the green ones, at least when they are young.

In the second edition of this manual (p. 195), I have already referred to the nitrogen poverty of the non-pigmented parts and there expressed the following opinion:—in the normally nourished leaf cell so much cytoplasm is present that not only material can be furnished for the development of the cell wall, but the chloroplasts can also be produced abundantly.

If the supply to the young cells is cut off too soon, because the material, increasing the amount of protoplasm, is supplied too scantily, and the cell wall becomes old prematurely, the cell can have performed only the first part of its task, the formation of the wall, and has nothing left over for the formation of the apparatus which produces reduction and increases the dry substances, nor for its maintenance. This same poverty must occur in the normal cell if it gets into conditions of growth which cause an accumulation of destructive, i. e., amylolytic enzymes, whereby it is again carried back toward the young stage. If the plant is brought under conditions which favor normal vegetative activity (shade, moisture and heat) the non-pigmented parts of the axis tend to produce green leaves. A discovery of Lindemuth's confirms this observation. He proved that intense light actually favors albinism. Ernst[1] mentions that in Caracas *Solanus aligerum* Schlecht., common to that region, is found not infrequently with variegated leaves. This occurs, however, only on *poor soil.* Specimens with *strongly variegated leaves, transplanted to better soil,* become green. With *Urtica dioica,* Beijerinck[2], even in one year, succeeded in bringing back the green form from the variegated form by means of cuttings.

Tissues, with a less concentrated cell sap are, however, less resistant. Actually, the white leaved parts of the plants are more sensitive to heat, frost, and drought, and die sooner. We find more abundant examples in the white leaved *Acer Negundo,* in which even the bark of the branches becomes variegated. Almost every year, summer sunburn and winter frosts kill the most exposed branches. Such cases also occur in conifers[3]. In the same way seedlings with white cotyledons and plumules are very easily destroyed. Not infrequently I have found pure white seedlings, or white ones with a reddish tinge, in larger sowings of various kinds of fruits. These were always treated with special attention but died after some time, in case they did not begin to produce green leaves. Similar observations have been made also by others, for example, on *Phormium tenax* (de Smet), *Passiflora quadrangularis* as well as on *Dahlia variabilis, Dianthus Caryophyllus,* and the Liliacea (Lindemuth). *A scarcity of reserve substances* in non-pigmented branches explains also the further observation that their cuttings grow with greater difficulty than those from the green parts of the same individual. Consider, for example, hydrangeas with pure white leaves and geraniums from the group "Miss Pollack."

Lindemuth observed in Abutilon that the non-pigmented leaves are usually smaller and have a shorter life period. We would recall in this connection the phenomenon, occurring not infrequently, in our wild plants, that when one-half of the leaf is white, the other half green, the former remains shorter and the latter, on this account, curves about the white half in the form of a sickle. (Cichorium, Beta.) In marbled leaves, the white

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1 Botanische Miscellaneen. Bot. Zeit. 1876, p. 37.
2 Beijerinck, M. W., Chlorella variegator, ein bunter Mikrobe; cit. Bot. Centrabl. G. Fischer, 1907, p. 333.
3 Zeitsch. f. Pflanzenkrankh. 1896, p. 361.

fields of a leaf often appear distended, the green ones wrinkled, or blistered. The stems also at times, in the non-pigmented part, show some shortening, as is proved by the variegated *Kerria japonica,* of which green shoots on the same stem and of the same age are at times half a meter taller than those bearing white leaves. Sambucus, Weigelia and others, behave in this way.

In my opinion, albinism is a form of arrested development which occurs more rarely in wild plants but to an increasing degree in cultivated ones and manifests itself in the poorer nourishment of the different tissue elements. The result of this is that, either the chlorophyll apparatus does not mature at all, or soon falls victim to destructive enzymes. The lack of any accumulation of reserve materials, or, at most, a scanty one, is connected with this and explains the increased collapsibility of the tissues.

Of the causes producing albinism, the pressure conditions in the bud should come first under consideration which arrest the development of the conducting system and thereby hinder the sufficient filling of the cells with plastic material even in the embryonic condition. This would explain the phenomenon of the sudden development of a non-pigmented shoot from the bud of a plant which had been green up to that time. In regard to cultural influences, experience shows that a relative excess of light acts favorably, for we see that often a condition of pure white leaves occurs very intensively with direct, strong insolation and is retained longest, but decreases, when shade and a sufficient supply of water and nitrogen give the leaf time to develop more slowly and let its vegetative functions act longer, i. e., preventing a premature end of life.

Timpe[1] cites in his latest work a phenomenon which has been repeatedly tested experimentlly. He repeated the experiments first described by Molisch[2] with the white and green variegated species of *Brassica oleracea acephala* and obtained the same result, viz., that the brilliant white color of the leaf surfaces, which reaches its greatest development in winter in a cold frame (up to February), decreases almost at once and finally disappears if the plants are brought into a warm place. Molisch transferred white variegated plants from the cold frame at 4 degrees to 7 degrees C. into a hot bed at 12 to 15 degrees C. All the leaves already formed turned green in from 8 to 14 days; those newly formed appeared green at once. Returned to the cold frame, the specimens again formed leaves variegated with white. Here belongs also Weidlich's statement[3] that *Selaginella Watsoniana* must be cultivated in a temperature of 10 degrees C. if it is to form white tips. In these cases, therefore, the increase in the vegetative functions, producing the loss of albinism, is conditioned by the increase of heat; while in other cases, according to the nature of the plant and other local nutritive conditions, the variegated leaves can be brought back to the optimum of their

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[1] Tempe, Heinrich, Panachierung und Transplantation. Jahrbuch d. Hamburg. wiss. Anstalten XXIV, 1906, Beiheft 3.

[2] Ber. d. Deutsch. Bot. Ges. XIX, 1, p. 32.

[3] Gartenflora 1904, p. 585.

functions and to the normal formation of chlorophyll by decrease of light and heat; or by the increase of the nitrogen or potassium supply, thus prolonging the period of growth.

A scanty supply of material frequently manifested in the increase of tannin and the absence of starch, the small size of the cell and the increase of the intercellular spaces, is also emphasized by Timpe in his carefully worked out experiments. He describes a phenomenon for Ulmus which seems strange to him but is exactly the best proof of our theory. In this the luxuriant spring growth of shoots variegated with white developed perfectly green foliage after the tree had been set out; but the midsummer growth, with a lack of water and excess of light and heat, again showed the variegation*.

If, however, albinism consists in the premature ending of life, i. e., in the suppression, or arrestment, of the work of the chlorophyll apparatus, the destructive enzymes, even if not increased in absolute amount, still obtain a preponderance in the cell because those which cause the formation of the reserve materials, have been too little developed due to the lack of chlorophyll activity. The equilibrium otherwise formed in the cells containing chlorophyll is destroyed.

We, therefore, do not need to assume the formation of a "virus":— a group of materials acting poisonously, which must be produced and increased in the plant,—in order to explain albinism and the phenomena of disease related to it (the mosaic disease, shrivelling disease, etc.). It is simply a change in the functions, i. e., a different direction of the molecular motion to which we must trace back, however, all metabolic processes. If this changed formation of substances is a movement, it can continue until some other form of molecular motion causes its arrestment. The non-pigmented part of the plant is, therefore, the carrier of an abnormal motion in its substances and on this account it would not seem strange if this motion is continued as soon as the paths, i. e., the vascular bundles (according to Pantanelli, the leptome parts), of two separated individuals are united, as is the case in grafting.

If we consider albinism not as a phenomenon coming from the ranks of the other phenomena of variegation but only as the most extreme case of a process representing a decrease in the amount of chlorophyll, it can no longer seem strange that plants, variegated with yellow and, therefore, less irritated, can still be brought to the production of seeds in which the same direction of the metabolic motion is continued, i. e., that the seeds furnish plants with yellow variegation.

The Mosaic Disease of Tobacco.

The most recent authors, who have written on albinism, have already mentioned the relation of this phenomenon to the mosaic disease of tobacco.

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* Loc. cit., p. 68.

This name originated with Adolph Mayer, who in July, 1879, when the disease had occurred to an alarming extent in Holland, received some diseased plants from the Society of Agriculture (Department Wijk bij Duurstede) for investigation. He published the results of his experiments in 1885, in a Dutch periodical and in the following year in the "Landwirtschaftlichen Versuchsstationen"[1]. According to F. W. T. Hunger[2] Van Swieten in 1857 had first called attention to the mosaic character of the variegated leaves of tobacco in the Dutch plantations but in his later studies on the cultivation of tobacco in Cuba, did not mention the disease which then was called *"Rost."* At present the disease may exist in any country growing tobacco and, accordingly, has received any number of names. Thus Hunger mentions that in Holland it is not only called "Rost" but in places "Bunt" or "Fäule." In Germany the name "Mosaikkrankheiten" holds good. In places it passes as *"Mauche;"* in France it is called *"La Mosaique"* or *"Nielle"* or *"Rouille blanche;"* in Hungary it is called *"Mozaikbetegsege"* and the Tartars in southern Russia call it *"Bosuch."* In Italy it is described under the name *"Mal de Mosaico,* or *"Mal della bolla."* In America, in the northern states, it is called *"Calico"* or *"the Frenching disease;"* in the southern states, on the other hand, *"Brindle"* or *"Mongrel disease."* The plantations in Java, Borneo and Sumatra also suffer heavily. The Javanese call the disease *"Poetih,"* while it is known in Deli by the Chinese name *"Peh-sem"*[3].

The mosaic disease may at present be considered the most dangerous disease of the tobacco plant. This explains why it has been thoroughly studied recently from several points of view but the results are often contradictory. While some investigators, retaining the old theory with great tenacity, wish to find microbes and think they have found them, others defend the theory that an infection disease is present here, the cause of which must be sought in inexpedient enzymatic activity.

The diversity of opinion is explained partially by the fact that different phenomena have been included under the mosaic disease which do not belong together. On the other hand, however, the disease can actually appear under different forms.

We follow Delacroix[4] in describing its symptoms. He distinguishes two stages:—1, loss of color; 2, changes in the form of the diseased leaves. In the first group of symptoms, the edge of the leaf shows sharply outlined, various colored spots of a faded green, which shades off into a whitish color but not into a yellow green as in *chlorosis;* the pale green parts have spots of dark green color, which is even darker than that of the normal leaf. The differences in color become more apparent when the leaf is held

[1] Mayer, Adolf, Die Mosaikkrankheit des Tabaks. Landw. Versuchsstat. 1886, Vol. XXXII, p. 450, Part III.

[2] Hunger, F. W., Untersuchungen und Betrachtungen über die Mosaikkrankheit der Tabakspflanzen. Zeitsch. f. Pflanzenkrankh. 1905, p. 257.

[3] Hunger, loc. cit.

[4] Delacroix, Georges, Recherches sur quelques maladies du Tabac en France. Paris 1906, p. 18. Extrait des Annales de l'Institut national agronomique, 2 ser., Vol. V.

against the light, and, by feeling the leaf, it is noticeable that the dark green places are somewhat thicker than the pale ones. Before Delacroix, Iwanowski[1] had already emphasized the fact that the lateral shoots, developing from the axes of diseased leaves, have the mosaic disease. This circumstance is very important and characteristic of the disease in which the loss of color occurs in the young leaves; as a rule, mature leaves do not become diseased. Often the dark green places become somewhat convex so that the surface of the leaves is somewhat wrinkled; in other, and rarer cases, a reduction of the leaf surface sets in which can increase to such an extent that, on the whole plant, only the mid ribs are present but no blades. This latter characteristic has been mentioned by Heintzel[2] and Iwanowski, but, according to Hunger[3] it is not typical of the disease, for he had also observed it in Deli in healthy plants on open ground.

Therefore, in the mosaic disease, we find the same characteristics as in albinism; a sharp delimitation of the spots, a greater thickness of the green places, and, at times, a reduction of the leaf surfaces, which, in the variegated parts, remain small. This can also be transmitted artificially and probably follows the same paths, i. e., the leptome. The only difference is that the mosaic disease can be transmitted considerably more easily. Every particle of sap which falls from a diseased plant into an injury in a healthy one is enough, under certain circumstances, to cause infection. We will cite, as example, the description of an infection experiment made by Koning[4]. On the 5th of July he cut the stem of a perfectly healthy plant as far as the vascular bundles and inserted in the cut a small piece of the spotted leaf from a diseased plant. On the 20th of July a dark fleck could be seen near the edge of a young leaf, between the veins. In the course of the next few days, specks appeared also on the other young leaves while the leaf itself took on "an uneven, irregular appearance due to the increase of the palisade tissue." The edge of the leaf appeared in places to be strangulated, or slightly lobed. Later these spots dried up, after having assumed a reddish brown color. Koning perceived concentric zones in the larger spots, of which the outermost zones were the darkest. Not infrequently he found that whole pieces had fallen out of the leaf. The latter characteristics are not mentioned by other observers, which fact supports our theory that the disease can present different aspects in different places and in different varieties of tobacco.

Koning gives only scanty notes on the anatomy of the diseased leaves. In the very youngest stage of the spots, where no differentiation of palisade and spongy parenchyma has set in, dark stripes appear between the cells which represent strikingly large, air-filled intercellular spaces. These are

1 Iwanowski, D., Über die Mosaikkrankheit der Tabakspflanzen. Zeitschr. f. Pflanzenkrankh. 1901, p. 1 ff.

2 Heintzel, Kurt, Kontagiöse Pflanzenkrankheiten ohne Mikroben mit besonderer Berücksichtigung der Mosaikkrankheit der Tabaksblätter. Inaug.-Dissert. Erlangen 1900.

3 Loc. cit, p. 274.

4 Koning, C. J., Die Flecken- oder Mosaikkrankheit des holländischen Tabaks Zeitschr. f. Pflanzenkrankh. 1899, p. 65.

retained in the advancing development of the tissue. No change can be observed at first in the epidermis. It shrivels later, becomes brown and dry when the chlorophyll has disorganized in the underlying tissue and the cells dry up.

In extensive plantations the infection of the plants usually takes place through contact with the hands of laborers who produce wounds when thinning out the plants and otherwise working among them. The touching of such places with fingers covered with sap from diseased plants is enough to inoculate the majority of the healthy plants. The process has often been tested experimentally. In an experiment made especially for this purpose in Holland, Koning determined 80 per cent. of disease.

The disease, moreover, is not restricted to tobacco, for Woods[1] had already reported that he could call forth similar phenomena when pruning tomato plants. Hunger[2] showed as an example that, in the same plant species, different varieties behaved differently according to their origin. He found in direct experiments with the heads of plants in Buitenzorg that all the shoots (lateral shoots) of 50 examples raised from American seeds had the mosaic disease. Of 25 plants grown at the same time from German seed 9 were diseased. On the other hand, the shoots of the 25 specimens raised from Indian seed showed no change.

In speaking of the cause of this disease, we have already mentioned that part of the observers assume the presence of micro-organisms without having seen them. Iwanowski, in fact, describes a specific bacterium, but Hunger found, in subsequent investigations, that the alleged organism disappeared from the cell with the use of the chloral hydrate phenol mixture. We can, therefore, say that no parasitic organism is known, as yet, for the typical mosaic disease, or, rather, the majority of exact observations lead to the theory that a physiological disease is concerned here, the transmission of which takes place by means of carriers which, advancing in the infected organism, cause, in the existing normal group of substances, the same changes in the arrangement which produce the disease and in this way the spread of the disease. The different degrees of susceptibility of the different varieties—those with thick leaves being much more resistant than those with thin leaves—prove that some *predisposition* must exist. The highly prized Deli tobaccos (those with the tenderest leaves) suffer most. The influence of cultivation is shown by the fact that *virgin soils* give decidedly smaller percentages of sick plants than those already used repeatedly for the cultivation of tobacco (cf. Hunger's field experiments)[3].

Two points of view are now held by the investigators who do not recognize microbes as the cause of the mosaic disease. One group believes that the plant produces a poison, *a virus*, which is capable of producing the same poisonous substances in the cell content of an inoculated plant, thereby

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[1] Woods, A. F., Observations on the Mosaic disease of Tobacco. U. S. Dept. of Agriculture, Bull. No. 18, May, 1902.

[2] Loc. cit., p. 287.

[3] Zeitschr. f. Pflanzenkrankh. 1905, p. 289.

causing the disease. Beijerinck[1] appeared first among those who hold this opinion. In 1898 he described a *"contagium vivum fluidum"* as the cause.

Hunger says further[2], "I consider the virus of the mosaic disease to be a toxin which is *always* produced in the tobacco plant during the metabolism of the cells but, in normal cases, exercises no effect, while it accumulates when the metabolism is too strongly increased and then causes disturbances such as the mosaic form of variegated leaves." I assume that the toxin of the mosaic disease, which is produced primarily by external stimuli, is capable, when penetrating into normal cells, of exercising a physiological contact effect with the result that the same toxin is formed there secondarily. In other words the *toxin of the mosaic disease possesses the peculiarity of acting as a physiologico-autocatalytic agent.* In this way the virus can be make its way independently throughout the tobacco plant and, reaching the paths leading to the meristem, can exert its influence there on the young structures. This explains the capacity of the diseased substance for increase. "This capacity does not depend on the active reproductivity of the virus itself but simply arises from the passive reproductive power of the living cell substances."

In contrast to the theory of poison we represent a second theory and call attention to the experiments of Pantanelli and others who have proved a change in the amount and action of the enzymes. Heintzel[3] says (1899, p. 45), "The enzyme which causes the mosaic disease may, therefore, be considered an oxydase." Accordingly, the cause of the mosaic disease would be present also in a healthy plant and would have an abnormal action only under special circumstances. Woods[4] expresses exactly the same theory since he thinks only certain conditions are concerned under which the oxidizing enzymes become effective—"either become more active, or are produced in abnormally large quantities." The condition of matters at present is still uncertain and forbids a closer examination of the relations. For the theory which we advance and have described in the first section of this chapter, the question is less important, whether an increase of the oxydases actually takes place, or whether a decrease of the reducing substances, always accompanying the oxydases, whereby the same amount of oxydase has an increased activity. Hunger has actually proved that the leaf with the mosaic disease contains less reducing and tannic substances than do healthy tobacco leaves[5]. A scantier sugar content has been proved in the diseased leaf, corresponding to a lack of chlorophyll; besides this,

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[1] Beijerinck, M. W., Over een contagium vivum fluidum als oorzaak van de Vlekziekte der tabaksbladen. Koninkl. Akad. van Wetenschappen te Amsterdam. Nov. 1898. Über ein Contagium vivum fluidum als Ursache der Fleckenkrankheit der Tabaksblätter. Centralbl. f. Bakeriologie 1899, Part II, No. 2, p. 27.

[2] Loc. cit., p. 296.

[3] Heintzel, Kurt, Kontagiöse Pflanzenkrankheit ohne Mikroben, mit besonderer Berücksichtigung der Mosaikkrankheit der Tabaksblätter. Inaug.-Dissert. Erlangen 1900; cit. by Hunger, loc. cit., p. 269.

[4] Woods, A. F., The destruction of chlorophyll by oxidizing enzymes. Centralbl. f. Bakt. 1899. Part II, Vol. V, No. 22, p. 745.

[5] Hunger, F. W. T., Bemerkungen zur Wood'schen Theorie über die Mosaikkrankheit des Tabaks. Bull. d. l'Inst. Bot. de Buitenzorg 1903, No. XVII.

less free organic acids are found[1]. Accordingly, the parts suffering with the mosaic disease lack the ability to form sufficient reserve substances; and thus the mosaic disease, which, according to Hunger[2], may also be transmitted without the existence of any injury, simply by contact with the hand, or, in grafting, be transmitted to the stock, belongs under albinism.

While we still have no reason for restricting the last named phenomenon, because the white variegated plants, in spite of their greater sensitiveness, form desirable specimens for our gardens, yet, the need of earnest regulations for combatting the mosaic disease, is most imperative and these have often been tried. According to Koning liming the soil has proved to be the best method. Hunger also proved good results by fertilizing with bone meal and gives warning primarily against an excessive chemical fertilization. In my opinion the disease is a result of inbreeding, which can be overcome successfully by decreasing the supply of nitrogen and by increasing the lime.

Wood says[3], "Overfeeding with nitrogen favors the development of the disease and there is some evidence that excess of nitrates in the cells may cause the excessive development of the ferments causing the disease."

The choice of seed also deserves especial attention as is evident from the statements of Bouygeres and Perreau[4]. These investigators took seed from plants, in the midst of a diseased field, which up to the time of harvesting had remained free from the mosaic disease. They obtained 98 per cent. of healthy plants. These were, at any rate, capable of being infected in wounds brought in contact with parts having the disease. Special consideration should be given primarily to the soil. In earth, on which tobacco had been grown for some time, healthy seed very easily became diseased[5].

Pox of Tobacco.

We have mentioned already, in discussing the mosaic disease, that other phenomena of discoloration have often given rise to much confusion. An example of the latter is furnished by the pox disease. Iwanowski and Poloftzoff[6] have called attention to the difference between this and the mosaic disease. For three years they studied this disease in Bessarabia, having been commissioned by the Russian Department of Agriculture. According to Hunger[7], the disease manifests itself in the appearance of

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[1] Hunger, De Mozaik-Ziekte bij Deli-Tabak. Deel I. Mededeelingen uit S'Lands Plantentuin LXIII, Batavia 1902.

[2] Hunger, On the spreading of the Mosaik-disease (Calico) on a tobacco field. Extr. Bull. d. l'Institut Bot. de Buitenzorg 1903, No. XVII.

[3] Observations on the mosaic disease of tobacco, Washington 1902, p. 24.

[4] Bouygeres et Perreau, Contributions a l'étude de la nielle des feuilles du tobac. Compt. rend. 1904, CXXXIX, p. 309.

[5] Behrens, J., Weitere Beiträge zur Kenntnis der Tabakspflanze. Landwirtsch. Versuchsstat. 1899, p. 214 ff and 482 ff.

[6] Iwanowski und Poloftzoff, Die Pockenkrankheit der Tabakspflanzen. Mém de l'Acad. Imp. de St. Petersbourg 1890, sér. VII v. XXXVII.

[7] Hunger, Zeitschr. f. Pflanzenkrankh. 1905, p. 297. Here also pertinent bibliography.

numerous small white specks at times of great drought, while in Deli the mosaic disease is observable immediately after sharp rainstorms. The cause is looked for in conditions similar to those in the mosaic disease.

White Rust of Tobacco.

A further phenomenon has been confused with the mosaic disease which is called "White Rust." Delacroix[1] has called attention to the fact that, in this the mature leaves, and not the young ones, become sick first. The spots are more numerous but are smaller and stand out in sharp relief. Ultimately they are bounded by a cork layer. The cause is said to be a micro-organism, *Bacillus maculicola.*

The Disease of the Peanut in German-East Africa.

According to Karosek[2] *Arachis hypogaea,* one of the most important cultivated plants of the East African colony, is in general but little attacked by disease. In the neighborhood of Tanga and Lindi, however, a phenomenon has now appeared to a considerable extent which recalls the mosaic disease. The leaves, blossoms and fruit remain small, the yield is scanty; whitish, irregular spots appear on the leaves, deforming them somewhat. The leaves finally become brown and die. Fungi have been found and any lack of nutrition is out of the question.

The Shrivelling Disease of the Mulberry.

This disease, at present widely distributed through Japan, which surely will be found later in Europe, has only been observed more exactly for possibly the last twenty or thirty years and has been studied earnestly only during the last ten years. According to Suzuki[3], whose description of the disease we follow, it is called *Ishikubyo* or *Shikuyobyo* in Japan. Like the mosaic disease, this shrivelling disease also occurs most extensively in the tender leaved and quick growing varieties. Within the same cultural varieties the individuals suffer most strongly which receive too much liquid fertilizer, while trees planted in poor soil, or in mountainous regions, are almost free from it.

The fact that the disease became noticeable at about the time when the so-called "pruning method" was universally introduced into Japan is of especial importance. This method consists in the cutting down of the trunks, or branches, at the time of the most luxuriant leaf development (May to June), close to the soil when the plant is three years old. The stock at once produces new, luxuriant shoots which by September have become 5 to 6 feet tall. These branches, in the following summer, are cut back again, either close to the soil or several feet above the surface. Specimens, which have been cut back for a long time, suffer less from the disease

1 Delacroix, G., La rouille blanche du tabac et la nielle, etc. Compt. rend. 1905, CXL, p. 675.

2 Karosak, A., Eine neue Krankheit der Erdnüsse in Deutsch-Ostafrika. Gartenflora 1904, p. 611.

3 Suzuki, U., Chemische und physiologische Studien über die Schrumpfkrankheit des Maulbeerbaumes, eine in Japan sehr weit verbreitete Krankheit. Zeitschr. f. Pflanzenkrankh. 1902, p. 203.

and it is absolutely unknown in regions where the plants, under the old cultural method, have not been cut at all. Consequently, we may maintain with certainty that a phenomenon resulting from intensive cultivation is concerned here. The fact that the plants remain healthy, which were cut back in autumn or the early spring *before the opening of the leaves,* favors the theory that this cutting during the time of making growth is the cause of the shrivelling disease. Diseased plants can be cured if left unpruned for several years.

The first indication of the disease appears generally when the young branches, breaking out from the stump of the trunk, have reached a height of one foot. First of all, the uppermost surfaces shrivel or show other phenomena of weakness. This change advances gradually downward, while the leaves turn yellowish or dark green, or even can retain their normal color. This usually sets in slowly since, in the first year, only the upper leaves of some shoots become diseased. In the course of time, the condition so spreads that the tree dies. There are, however, also acute cases in which all the leaves shrivel at the same time in one year. The branches of the diseased plants are usually very thin and develop very numerous side branches and leaves; they droop at times and lose their stiffness. The roots begin to decay.

Naturally, parasites have often been held responsible for this disease and the phenomenon has been declared to be the result of a parasitic decay of the roots but the roots are demonstrably healthy in the first stages of the disease of the aërial parts; besides this, it seems very remarkable that a parasite always seeks only the trees treated with the pruning method.

With due consideration of the preceding facts, one is forced to the conclusion that a continued disturbance of equilibrium in the nutritive processes must be the cause here. This is confirmed by Suzuki's numerous analyses. He found, for example, in the average from ten experiments that in leaves of plants suffering from the shrivelling disease, when the content of the healthy leaves is set at 100, the water content is 94.7 per cent.; the dry substance 116 per cent. In 100 parts dry substance the content is:—

(normally valued at 100)

Protein	81.8 per cent.
Fat	86 "
Raw fibre	81.4 "
Extractive substances free from nitrogen	120 "
Pure ash	91 "
Total nitrogen	81.8 "
Albuminoid nitrogen	86.8 "
Non-albuminoid nitrogen	66.6 "

In 100 parts ash content.

(normally valued at 100)

$Si O_2$	113.1 per cent.	$K_2 O$	92.3 per cent.
$S O_3$	97.2 "	CaO	105.5 "
$P_2 O_5$	101.6 "	MgO	120.6 "

Therefore, a greater abundance of ash in proportion to the organic substances produced, as has been emphasized already as typical for all defective plants.

The characteristic of the shrivelling disease of the mulberry is a congestion of starch in the diseased leaves and a very scanty development of the wood body, especially of the conducting elements, the sieve tubes. Because of the scanty number and small breadth of the lumina of these elements, only a very slow transportation of the assimilated material (here especially sugar) can take place. Consequently the continued dissolution of the starch is prevented[1]. Besides these anatomical conditions, chemistry now proves the presence of an abnormally large quantity of oxydases and peroxydases. According to Woods, it is very probable that the oxydases not only destroy all the chlorophyll but also prevent diastatic and proteolytic action. On this account, they might be the cause of the delay in the transportation of the starch and nitrogen compounds. At any rate, Shibata[2] maintains, as a result of his experiments, that the diastase action is not prevented by the oxydase and that a further production of the enzymes would be caused by the entire elimination of the elaborated materials. Later experiments must make clear which of these theories is correct. The fact is sufficient for us here that the *whole amount of the reserve substances* is exhausted in the sick plants[3]. This is shown also in the scanty filling with starch of the bark on the branches and roots and of the dormant buds, and manifests itself also in the decrease of root pressure and the transpiratory intensity (Miyoshi). It is now clear that if a plant is continually forced to use its reserve material by the removal of its foliage, it does not have time enough to mature the new growth, i. e., to deposit sufficient starch, albumen and cellulose in these organs.

The curing of this disease will lie in a return to the normal fall pruning. As soon as branches of diseased plants have developed their own roots by layering, they develop normally as Suzuki has shown experimentally.

Besides this, very similar phenomena of disease also occur in the *tea plant* as soon as the picking of the leaves is carried on irrationally.

The Sereh Disease of the Sugar Cane.

At present the Sereh disease, which appeared in Java in the 80's of the last century and is advancing from the West to the East, is, indeed, the most greatly dreaded disease of the sugar cane. It has now been observed also in Réunion, Sumatra, Borneo, Malakka, the Mascarrean Islands, and in Australia[4]. According to Krüger[5], whom we follow first of all, the name

[1] Miyoshi, M., Untersuchungen über Schrumpfkrankheit ("Ishikubyo") des Maulbeerbaumes. II. Journ. Coll. Sc. Tokio 1901, Vol. XV.

[2] Shibata, K., Die Enzymbildung in schrumpkranken Maulbeerbäumen. The Botanical Magazine XVII, 1903.

[3] Suzuki, loc. cit., p. 277.

[4] Cit. Zeitschr. f. Pflanzenkrankh. 1901, p. 297.

[5] Krüger, W., Über Krankheiten u. Feinde des Zuckerrohrs. Ber. d. Versuchsstation f. Zuckerrohr in West-Java, Kagok-Tegal. Dresden, Schönfeld's Verlag, 1890, p. 126.

originates from the Javanese name for *Andropogon Schoenanthus* (Jav. Seréh), grown extensively in gardens there. This grass forms unusually greatly branched bushes. In its most highly developed form the disease of the sugar cane also appears in an excessive formation of short lateral shoots which make the plant look bushy. The root system is poorly developed and only slender roots spread out in the soil; the majority remain short and bushy, for their tips die and those formed anew fall victim to the same fate. Many parasites are found in the dead tissue; among these, *Tylenchus Sacchari* Soltw. is the most common in Java. The internodes of the stem remain short; the eyes of the leaf axils swell up round, while, in the normal cane (with the exception of a few varieties) they lie flat like a shell in the small depressions on the stem. The growth of the main shoot is suppressed and, on this account, the lower eyes, especially those below ground, develop quickly. In the new shoots, however, the same process of suppression of the apical growth is repeated immediately as well as that of the breaking of the secondary axes. In this way the whole plant gets an obnormally bushy formation. The Javanese material, which I ordered for investigation, at times showed such a ramification of the lateral axes on the upper, higher parts of the stem that groups, resembling witches' brooms, were formed. All possible transitions between this bushy dwarfing and the slender normal condition are found in the different stages of the disease.

As a result of the great shortening of the internodes, the leaves stand close to one another like fans. The leaf sheaths seem to enclose each other. In many cases, their death does not take place as it does normally by advancing from the edge towards the mid-rib, but conversely, and the result is that they remain for a long time on the stem and form nests for micro-organisms. Their color is usually darker than that of the normally dead leaves and while the latter are tough, the abnormal ones are more brittle and disintegrate easily. The intensive red colored vascular bundles are at once conspicuous in a cross-section through a node of the diseased cane. This coloring matter may be withdrawn with alcohol. The cell walls are frequently *swollen out of shape* and partially destroyed.

This red coloring of the bundles occurs in cuttings and in older plants in the first stages of the disease, so that it was thought that they should be emphasized as a characteristic especially deserving of consideration.

We have observed this red coloring of the cell walls in many non-parasitic diseases of monocotyledons, and Busse[1] has been able to produce it artificially in the sorghum millet in German East Africa by painting the leaf blades with vaseline or paraffine oil. The color spread still further in the xylem parts of the vascular bundles and was traced by Busse to a disturbance in the respiratory process. We consider the red color to be a phenomenon of oxidation which indicates a functional disturbance in the con-

[1] Busse, Walter, Untersuchungen über die Krankheiten der Sorghum-Hirse. Arb. d. Biol. Abt. f. Land- u. Forstw. am Kaiserl. Gesundheitsamte 1904, Vol. IV, Part 4, p. 319.

ductive system due to very different causes but especially frequent in root diseases. It appears also very clearly in the pineapple disease, in a parasitic disease of the sugar cane produced by *Thielaviopsis ethaceticus* which can be transmitted by cuttings. The greater the amount of sugar in the stem—this increases constantly from the base up to about the middle of the stem—the more easily the cuttings become diseased by the fungi[1]. The red color appears in the Sereh disease at times isolated in some nodes, while the fibrovascular cords of the underlying internodes are still uncolored. It may be concluded from this that the disease represents a general ailment, a constitutional disease, which shows its first visible symptoms in especially weakened places.

The cause of the disease has been sought in all kinds of influences; exhaustion of the soil, degeneration due to continual asexual propagation, abnormal atmospheric conditions, unsuitable fertilization, especially with peanut meal (Bungkil), too deep planting, or too high covering with earth, too early, or too late planting, and finally parasites. Among the latter, nematodes, fungi and bacteria come under consideration.

The conclusions of one scientist contradict those of another. Thus, for example, Krüger states that he has found bacteria in the ducts as a constant accompaniment of the disease, while Tschirch[2] considers it impossible that bacteria can be the cause of the disease and sees the initial stages in an injury to the roots. Benecke[3] sides with Krüger, Möbius[4] opposes the assertion of any existing degeneration and also seeks the cause in parasitic organisms. Ohl[5] perceives the cause of the Sereh disease and the disease of the coffee tree in Java, in which the leaves fall, to be the deforestration of the mountains and subsequent drought. Janse[6], in the same way, traces the disease to a lack of water, since he thinks that the gummy obstruction of the ducts prevents conductivity. He connects the formation of the gummy substance with bacteria (*Bacillus Sacchari*). Went[7] considers the Sereh directly as a gummosis which arises from the co-operation of a parasitic root and leaf sheath disease and which may be propagated by cuttings.

Wakker[8] considers the disease as a non-parasitic gummosis, associated with the excess of water which cuttings, developing during the dry monsoon, suffer in the following rainy period.

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1 Cobb, N. A., Fungus Maladies of the Sugar Cane. Rep. Exp. Stat. of the Hawaiian Sugar Planters' Association. Bull. 5, Honolulu, 1906, Part 1, p. 218.

2 Tschirch, A., Über Sereh, die wichtigste aller Krankheiten des Zuckerrohres in Java. Schweiz. Wochenschrift f. Pfarmazie 1891.

3 Benecke, Franz, Proefnemingen ter Bestrijding der "Sereh." Samarang 1890. For further treatises by this author cf. Zeitschr. f. Pflanzenkr. 1891, p. 354, 361.

4 Möbius, M., Over de gevolgen van voortdurende vermenigvuldiging der Phanerogamen langs geslachteloosen weg. Mededeelingen van het Proefstation "Midden Java" te Samarang. 1890.

5 Ohl, A. E., Eene Waterstudie. Batavia 1891; cit. Zeitschr. f. Pflanzenkrankh. Vol. I, p. 365.

6 Cit. Zeitschr. f. Pflanzenkrankh. 1893, p. 238.

7 Went, F. A., Die Serehkrankheit; cit. Zeitschr. f. Pflanzenkrankh. 1894, p. 235 and 1901, p. 297.

8 Wakker, J. H., De Sereh-Ziekte S. A. Archief voor de Java-Suikerindustrie. 1897, Afl. 3.

Thus the difference of opinion extends to the most recent times[1] without having led to any positive reconciliation. The reason probably lies in the fact that the characteristics given for the Sereh disease also occur in other diseases, as will be shown, for example, in the following section, and thus different investigators may have considered different forms of the disease.

We will emphasize a few facts from positive results, i. e. that healthy cane can remain healthy in plantations suffering from the Sereh disease, and that diseased cane remains diseased in healthy fields. It should be added further that often wide bands along the edges of the fields appear diseased first, or only the edges themselves, and that the Cheribon cane, which tends to disease when planted in mountainous regions, has given healthy cuttings. Some cuttings are practically immune, while others are susceptible. Even the cuttings of the same variety from regions free from the Sereh disease at first remain healthy, even in infected regions. It is evident from this that the disease can scarcely be parasitic but falls under the group of the gummoses. It can, therefore, not be contested that the bacterial gummosis conditions exist in the Sereh disease, just as in the rot of our sugar beets, but these forms also depend upon certain conditions of weakness of the plant body which we call displacement of the enzymatic functions.

We consider the causes of the insufficient ripening of the cane, i. e. non-deposit of reserve substances, cane sugar in this case, to be the inconsiderate cultivation of sugar cane with an increased supply of fertilizer and water on heavy soil in enclosed positions, etc. Actually, the loss in the sugar content is uncommonly great in the Sereh disease.

We are not in a position to determine the process which causes the lack of reserve substance. It is, however, a matter of indifference in judging of the disease, whether an excess of destructive enzymes is present or a paralyzation of the constructive ones. The metabolic processes, leading to this lack of cane sugar, are naturally present in the whole plant no matter where they make themselves felt symptomatically. Therefore, each smallest part of the diseased cane, even if it shows no symptoms of the Sereh disease, is actually predisposed to it and even contains the carriers of the disease. Consequently each Bibit (cutting) from the plant having the Sereh disease is condemned to death as soon as it comes under conditions favoring the disease. It heals itself, however, and returns to the normal enzymatic activity on tracts of land where the Sereh does not break out.

From this the best method is clearly the choice of varieties immune to Sereh or, at least, the cultivation of Bibits in open, mountainous positions and other localities which do not permit the disease to occur. Probably a change in cultivation takes place in such a way that only weak fertilizing and more porous soils, as well as open positions, are used in the cultivation

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1 Hein, A. S. A., Hypothesen en Ervaring omtrent de Sereh ziekte. De Indische Mercuur. Amsterdam 1905; cit. Jahresber. f. Pflanzenkrankh. v. Hollrung, Vol. VIII, 1906, p. 245.

of cane; these also cause a standstill in the Sereh disease in distinct centres of the disease.

We believe also that the diseases termed the rusts of sugar cane belong here. Of these, we refer here to the *Powdery Disease* described by Spegazzini[1]. which occurs also with red spots and a gummy secretion but becomes noticeable because of its unpleasant smell. The base of the stem suffers especially. A bacillus (*Bacillus sacchari*) may be isolated from the gummy slime which requires an acid nutrient substratum and produces a protein decay which gives rise to the offensive smell of the diseased cane. This disease also occurs with *Andropogon nutans*. In regard to the production of the red color in the vascular bundles and of the gum in the sugar cane by micro-organisms, Grieg Smith's[2] work is of especial importance. He found reddened vascular bundles in otherwise healthy cane as well as in the stems which had become gummy because of *Bacillus vascularum* Cobb. The red color was produced by the filling of the large ducts with a red gum just as in the Sereh and other sugar cane diseases. He found further a fungus, which produced a shiny, very scarlet color on nutritive media with dextrose but no gum, and gum bacteria in the diseased ducts, especially *Bacillus Pseudarabinus* n. sp. *Bact. Sacchari* ("this variety normally lives in the sugar cane") and besides this *Bacillus vascularum*. On sheets of nutrient agar with laevulose, the fungus produces no coloring matter, but in combination with *Bacillus pseudarabinus* a bright scarlet is produced and in combination with *Bact. Sacchari,* a rusty brown.

It will be seen from these examples how the constitution of the substratum is able to modify the parasitic activity and in what way, therefore, different aspects of disease are produced. A preliminary condition necessary for the production of the disease is, however, a deviation from the normal metabolic processes in cane. healthy up to that time, which favors an increase of bacteria (probably always present) and which appears sooner or later in the different susceptible varieties of cane but remains suppressed in the immune varieties.

Cobb's Disease of the Sugar Cane.

According to Erwin Smith[3], the Sereh disease resembles in many ways the disease of the sugar cane occurring in Australia (and especially in Mauritis, Java and Brazil), which Cobb describes. This latter disease is characterized by diminutive growth, shortening of the internodes, albinism, premature sprouting of the buds, and propagation by infected cuttings. It differs essentially, however, from the Sereh, since the heart of the cane stalk becomes lignified and masses of yellow slime (gum) occur constantly in the

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1 Spegazzini, La gangrena humida o polvillo de la canna de zucchero. Rivista azucarera. 1895.

2 Smith R. Grieg, Sidney. Bakteriolog. Laboratorium der Linnean Soc. of New South Wales. Centralbl. f. Bakt. usw. 1906. Vol. XV. No 25, p. 733.

3 Smith, Erwin, Ursache der Cobb'schen Krankheit des Zuckerrohres. Centralblatt f. Bakteriologie usw. 1904. Vol. XIII. Part 22, 23.

blood red bundles of the trunk. It has been proved by careful inoculation experiments that the cause of the disease is *Pseudomonas* (*Bacillus* Cobb) *vascularum*.

Smith considers the red coloration of the branches (corresponding to the brown coloration of bacterial gummoses) as a reaction of the plant. According to Prinsen Geerlings, a neutral uncolored substance, dissolving with difficulty, exists in the cellulose of the normal sugar cane, which turns yellow with the action of an alkali (like tannin), but becomes red, when aërated, and later brown.

The interesting result is the definite proof that certain varieties of cane (common green cane) in inoculation experiments show extraordinarily great susceptibility, while other varieties (for example, common purple cane) become only slightly diseased. The sap of the latter canes showed approximately a doubled acid content and Smith surmises that the high susceptibility to parasites depends "only on the weak acidity or the minimal occurrence of a specific arresting acid." Cobb reports that where such resistant varieties are grown the disease has disappeared.

To the same group of diseases belongs also the disease of the sugar beet which I first described as *"bacterial gummosis"* and later as *"beet tail rot."** So far as can be determined experimentally, the bacteria have an epidemic distribution only if continued heat and drought with abundant nitrogen fertilization weaken the growth of the beets. If wet weather sets in with the same excessive fertilization, the yield in sugar becomes considerably less, but the bacterial gummosis is lacking[1].

Peach Yellows.

Since 1887 a disease of the peaches in the United States of North America has been studied very earnestly. It has caused uncommonly great injury to extensive orchards. A yellow disease (chlorosis) is concerned here which is transmissible by grafting[2]. This condition of yellow foliage differs in this from the similar phenomena caused by a lack of nutrition, frosts, etc. In this disease, which has constantly increased in the last 20 years and has made the cultivation of the peach unprofitable in many places (in the Delaware and Chesapeake regions), a peculiar red mottled condition and a premature ripening of the fruit are very characteristic. To this should be added the premature development of the winter buds and the extensive development of latent and adventitious buds; therefore, a diseased branch as in the Sereh disease. Although the fruit, which at times has red stripes extending into the flesh, attains a normal size in the first year, it becomes smaller in the following years of the disease, and tasteless, or even bitter. The phenomenon is restricted at first to a few branches and then

* See v. 2 of the Manual, p. 42.

1 Zeitschr. f. Pflanzenkrankh. 1892, p. 280. 1896, p. 296, and 1897, p. 66. Blätter f. Zuckerrübenbau 1894, p. 1.

2 Smith, E. F., in Report of the chief of the Section of Vegetable Pathology. Washington, 1890. Smith, Erwin F. Additional evidence on the communicability of peach yellows and peach rosette. Washington 1891, Bull. 1.

extends gradually over the whole tree. At the same time the foliage begins to turn yellowish green in places and weakly pale shoots break out from the bark. The foliage developed in the following spring appears yellow, or a reddish green, the new shoots are stunted and their leaves roll and curl. At times the tips of all the healthy, slender shoots suddenly show a continually repeated formation of lateral axes which become weaker and weaker and whole nests of sprouts are produced (usually in the autumn). Death occurs sooner or later. In budding with healthy eyes from diseased trees, a large percentage of the budded trees seems to be sick and, in fact, not only the shoot developed from the eye itself, but also the stock, similar to the variegation in *albinism.*

The *rosette,* which occurs also in plums, was considered at first a variety of the peach disease here described, but later Smith held it to be a specific disease. Its course is uncommonly rapid, so that death occurs in the same year, or, at the latest, in the following year. Here, too, the leaf rosettes are produced by a strikingly abundant development of latent eyes and the development of lateral-shoots, which attain, however, scarcely one-sixth the length of normal shoots. These may develop other side shoots, which again branch. Such nests of branches often contain from 200 to 400 small leaflets and malformed stipules. At the bases of the shoots the leaves are larger and better developed but peculiarly rolled in at the edges and strikingly stiff, because of a certain rigidity of the mid-rib. These leaves turn yellow in the early summer and drop. In the course of the summer the rosettes dry up; the blossoms of the diseased shoots, however, do not develop earlier than those of the healthy shoots, but rather somewhat later. On the other hand, all the fruits which become gummy fall when still green and never show the red specking as in peach yellows. In both diseases the fine, lateral roots are found to be shrivelled and dead and the rosette disease is often accompanied by abundant gum centres. This rosette disease may also be carried to the stock in budding. Only, as a rule, very many more normal lateral eyes in a shoot develop into rosettes and, thereby, the bushy formation becomes denser than in the peach yellows.

Opinions as to the cause of this disease are divided, yet the bacterial theory has become less prominent since it has been recognized that in many cases mycelium and bacteria have not been found. For this reason the theory has become much more universal that a constitutional disease is concerned here, in which substances due to an abnormal metabolism may be transmitted by grafting as in albinism and the mosaic disease. In fact, here, the transmission probably takes place through the pollen, for Morse[1] has observed that out of three varieties of peaches, two became diseased, while the third, the white Magdalene, remained healthy. This variety could not be crossed with others.

[1] Morse, E. W. On the power of some peach trees to resist the disease called "yellows." Bull. Bussey Institution, Cambridge, 1901; cit. Zeitschr. f. Pflanzenkr. 1902, p. 58.

Of the unusually numerous practical experiments made especially by Smith[1], it can be only stated as a result, that no one has succeeded, as yet, in obtaining any indication of the cause. In ordinary years, a lack of nutrition, or its excess, can not be considered as a reason for the disease. Still it may be observed that rainy, cool summers show a decrease of the disease and dry periods, an increase. Grafting on the Marianna plum was found to be apparently a protection against the rosette disease, since the eyes from the diseased peach developed to healthy shoots. Infection experiments with about twenty different kinds of bacteria and yeasts, taken from the tissue of diseased peaches, gave no other result than a swelling in a few cases at the point of infection or an exudation of gum[2].

The almond suffers from both of these diseases and apricots and Japanese plums from the yellows[3].

In my opinion, injuries are concerned here which are produced by intensive cultivation and lack of consideration of the soil requirements of the peach. In the long run, all heavy soils, rich in fertilizers, become dangerous for the peach. In combatting this disease, it might be well to consider primarily cultivation on light soils and in open places.

Gummosis of the Cherry.

The exudation of gum is well known as a widespread phenomenon especially among the stone fruits and can be produced by very different kinds of causes.

With us, the cherry and the peach suffer most frequently from gum exudations. We sometimes find light yellow, transparent masses, at other times brown, cloudy solid ones, extending over a part of the bark of a branch or the trunk. These masses are soluble in boiling water; insoluble in alcohol and cannot be crystalized. When boiled with dilute sulfuric acid, the jam contains a sugar which can ferment and yields mucic acid when treated with nitric acid. They belong, therefore, to that group which organic chemistry terms Gums. Different varieties of gums have been distinguished, according to their capacity for swelling in water. Gum perfectly soluble in cold water is called *Arabin*, which has all the characteristics of an acid[4]. The gum tragacanth which swells up in water to a sticky jelly is a representative of the *Bassorin* group, and the modification of Bassorin is called *Cerasin*, which is soluble in boiling water. Cherry and plum gums are a mixture of Arabin and Cerasin. We may assume that the gum formed in gummosis changes its constitution according to the time of its production and the character of the tissues from which it is produced. It may have some relationship with pectin substances. Gum arabic has the character of an organic calcium salt.

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[1] Smith, E. F. Experiments with fertilizers, etc.; cit. Zeitschr. f. Pflanzenkr. 1894, p. 177.

[2] Smith, E. F. Additional notes on peach rosette. The Journal of Mycology, Vol VII, No. 3, 1893.

[3] Cit. Zeitschr. f. Pflanzenkrankh. 1896, p. 156.

[4] Czapek, Fr. Biochemie d. Pflanzen. Leipzig, 1905, Vol. I, p. 554.

We get the best insight into the nature of the disease by considering the young gummed lateral cherry branch illustrated in Fig. 155, 1 and 2. Isolated ducts are shown, first of all, in the middle of the normal wood, which are entirely filled with gum (Fig. 155 *2a*). This gum has been formed in part from the secondary membranes of the ducts. When treated with hydrochloric acid, which colors the walls of the wood cells and ducts a brilliant carmine, as well as the bast fibre cells, the breaking down of the still red wall of the duct into yellow gum, found here in drops, may be easily recognized. This phenomenon is frequently only a forerunner, or accompaniment of a much more extensive formation of gum, whereby large gum centres are produced in the wood and in the bark.

Even in one year old branches, it is possible to discover the first traces of the gummy exudation by examining closely cross-sections of young branches in which gummosis is recognizable to the naked eye only in the occurrence of extremely small black points. Lighter colored places appear at times in the wood body which, with more thorough investigation, are found to be composed of parenchymatous instead of prosenchymatous cells. This abnormal wood parenchyma (Fig. 155 *2 p.*) is usually enclosed by normal wood, which separates it also from the cambium (*2c*). As a rule, these lighter colored places, which are usually deposited side by side, parallel to the periphery, and usually separated by thin radial stripes of normal wood, are found in different developmental stages. Some are perfectly unimpaired; others show cells near the centre which have already changed to gum. In the same cases, all the abnormal parenchyma and, in the same way, the normal wood, are entirely changed to gum (Fig. 155 *2d*). In this, the intercellular substances are dissolved first of all; then follow the primary, and finally the secondary membranes of the ducts and the wood cells. In such large gum holes, a peculiar process of growth of some cells sets in, together with the simultaneous dissolution of the remainder. While the wood cells and ducts especially undergo gummosis, some medullary ray cells at first grow longer. The starch which they contain is dissolved; in a few, two new cells may be observed, which elongate in different directions. The medullary ray cells, lying more toward the centre and somewhat removed from the gum centre, round off and sometimes elongate. In this way arise many celled filaments, which remind one of certain algae (Trentepohlia) (Fig. 155 *m*) and which grow freely into the gummy mass. They are also dissolved, beginning at the outside, but this does not take place in any definite order. Often the cells at the tip of the filament are found dissolved, with the exception of a thin remnant of the walls. In other cases the cells at the base are dissolved and then the piece of the filament, which has become free, lies isolated in the gummy mass.

Very similar processes are found in the bark, the thin walled bast cells of which (Fig. 155 *b*) very easily succumb to gummosis. The gum centres are met with much more frequently in the bark than in the wood. In rare

Fig. 155. Year-old twig of sweet cherry with mature gum cavity and parenchymatous tissue aggregations in the healthy wood.

cases I have found the initial stages only in the cambium itself and, in fact, more frequently in the peach than in the cherry.

However, where the initial stages can be found, the evil is always dangerous because it spreads further. Gummosis produced in the wood soon spreads to the cambium and the bark, when it becomes very extensive in the bark, and thus may furnish the greatest part of the gum on the exterior of the trunk; the cambium also does not escape later. The assertion that gummosis always begins in the cambium is correct only if by cambium is meant the primordia of imperfectly developed cells which later fall victim to liquefication. The profess of liquefication itself can begin at any place in the branch and long after the formation of these tissues has taken place. On this account, we find gum holes in the middle of the wood body.

The ultimate result is essentially the same. At some point in the circumference of the trunk, the cambium is finally destroyed and the already matured wood becomes more or less diseased. A wound thus appears which spreads further and further. This, however, is not always recognizable externally, for the diseased place is not indicated by gum which has exuded to the outside. The gum comes to the surface rarely, or only very late, if the cambium is first attacked by gummosis. Then the solid, already matured wood dies slowly and, in fact, gradually more toward the centre of the trunk, i. e. toward the pith (Fig. 155 *2k*) than toward the circumference. This arises from efforts at localization, which occur simultaneously with the disease. A case illustrated in the drawing (Fig. 155 *1 g*) and occurring not infrequently, consists in the drying up of the bark above the affected wood, with the exception of a few bast bundles, and not its dissolution. At that place, the part marked *W* in the figure is bridged over by bark elements (Fig. *2 r*). The formation of gum is not very extensive but the attempt of the tree to heal the wound becomes more noticeable. This is perceptible in one-year-old branches. Figure 155 *1*, illustrating a gnm pocket a year old, shows at *u* the attempt of the tree to overgrow the place (during several years) : *a* indicates a branch.

A more abundant formation of wood and bark on the healthy part of the trunk, lying next to the wound (Fig. 155 *2 h*) makes the trunk thicker on the wounded side than on the healthy side (l') and above and below the wound. If the bark is retained above the wound the edges of the overgrowth (Fig. 155 *u*) have raised the dry bark from the dead wood and in this way a cavity forms of which the back wall is formed from the wood and pith partially attacked by gummosis and the front wall by the dry bark (not drawn in the figure) and the sides of the freshly formed callus (*u u*). The cavity thus produced is a lodging place for insects and fungi.

The newly formed callus, however, rarely remains intact. In the majority of cases, small gum centres (Fig. 155 *2d'*) are found in the luxuriantly developed new tissues. To be sure, the living bark attempts to enclose the diseased places by layers of cork, but I have never been able to

find a case of healing. The difficulty in closing the wound is explained by the presence of new gum centres in the callus.

We have the following points to emphasize from the consideration of the cherry branch affected by gummosis here illustrated. 1. The production of parenchymatous tissue groups between the prosenchymatous elements of the wood. 2. The position of the groups between two medullary rays which can curve about the parenchyma aggregations, and, more rarely, are able to participate in their formation. 3. The production of these groups independently of wounds. 4. The liquefaction of these tissue aggregations into gum pockets into which the resistant medullary ray cells grow like threads. The last circumstance is explained by the fact that in the same cambial ring zone of the branch, or trunk, the medullary cells develop more rapidly than the tissue lying between them, and, therefore, are elongated further radially into the bark body where they function as parenchymatous tissue. At the time when the process of liquefaction begins, the medullary ray cells, therefore, are tougher and more resistant and the first gummy centres appear as holes between two medullary rays when the gummosis is not caused by wounds.

The more recent experiments attempting to explain the production of gum exudation[1] begin with the phenomena of injury. Beijerinck and Rant[2] assert in their very thorough work that the gummy exudation depends "on the abnormal development of the embryonic wood tissue caused by the *wound* stimulus."

Beijerinck presents the subject thus: the normal plant forms cytolytic substances which take part in the formation of ducts and tracheids. The physiological gum, thus produced, is in fact usually entirely re-absorbed, yet, under certain circumstances, it remains demonstrable as such even in the cavities of the mature ducts. The "gummy exudation, therefore, depends upon an abnormal increase of the action of those cytolytic substances under the influence of dying cells, perhaps because an especially large number of these are produced in necrobiosis. By *necrobiosis* is meant the cell activity after the death of the protoplasm, while the enzyme bodies remain active."

Ruhland[3] opposes this theory. He calls attention first of all to the fact that gummosis can take place in seeds, fruits[4], leaves and also in the phellogen, on which last point he lays especial stress. He found considerable masses of gum in the youngest phellogen of *Prunus Cerasus* and thinks that

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[1] Compare the second edition of this manual for older points of view.

[2] Beijerinck, M. W., and Rant, A. Wundreiz, Parasitimus and Gummifluss bei den Amygdalaceen. Centralbl. f. Bakteriol. usw. 1905, XV, No. 12. Rant. A. Die Gummosis der Amygdalaceen. Dissertation, Amsterdam, 1906.

[3] Ruhland, W. Zur Physiologie der Gummibildung bei den Amygdalaceen. Ber. d. Deutsch. Bot. Ges. 1907, Vol. XXV, p. 302.

[4] The gum exudation appears especially frequently in plums in wet years. As a rule, it forms in little drops of gum as clear as water which come from wounds in the fruit flesh made by insects. Often no insect injury can be recognized, and then the places bearing the drops are usually harder and somewhat flattened. A considerable accumulation of gum is found in the fruit itself beneath these flattened places. I also found gummification of the pits of plums along the line of union of the halves, so that under slight pressure the two fell apart.

"a universal peculiarity of embryonic cells is concerned in this gummy dissolution which, however, does not extend so far as dissolution in normal life, but only when caused by some further impetus." Ruhland investigated the abnormal tissue groups, which may be observed in the production of the gum canal and found cells enlarged to vesicles with two fully developed nuclei but without the formation of any cell wall between them. The process is explained by the adjacent Fig. 156.

Therefore, the cell filaments, which extend into the gum centre, are produced by the "repeated divisions of a cell which, not diseased, lies at the base of the filament, while the daughter cells, thus produced, only increase in size without division." The normal process of wall formation is arrested in the embryonic cell and the carbo-hydrates, designed for the formation of cross walls, are transformed into gum substances. The reason for the change may be sought in the fact that, because of some *injury*, the embryonic

Fig. 156 Sections through gum-forming tissue (fixed with chrom-acetate, stained with safranin-gentian-violet orange. (After Ruhland.)

A a cell filament. *B* a young gum center. at *a* and *b* cells with two nuclei.

tissues are made accessible to the oxygen of the air; the carbo-hydrates, really destined for cross-wall formation, will then pass over into the gum which is richer in oxygen. Grüss[1] explains the oxidation by means of oxygen carriers which are formed in the tissue during growth. Wiesner[2] had earlier assumed a ferment which, like diastase, turns the guaiac emulsion blue and is destroyed by boiling. When treated with Orcin or hydrochloric acid, a red or violet color appears after a short boiling, and a blue precipitate forms. In the initial stage of gummosis, only the contents of the parenchyma cells are found to discolor in this way, from which it may be concluded that the ferment has its seat in the protoplasm. The ferment has been proved in the gums of seed and of stone fruit trees, in gum arabic and other kinds of gum. Ruhland's experiments with the removal of oxygen,

[1] Grüss, Über Lösung u. Bildung d. aus Hemicellulose bestehenden Zellwände und ihre Beziehung zur Gummosis. Bibl. bot Heft 39, Stuttgart 1896, Erwin Naegele.

[2] Wiesner, Über ein Ferment, welches in der Pflanze die Umwandlung der Cellulose in Gummi und Schleim bewirkt. Bot. Zeit. 1885, No. 37.

in which production of the gum centres was suppressed, show that a supply of oxygen seems to be an absolute necessity.

In our opinion, the necrobiosis theory of Beijerinck and Rant is untenable, since gummosis may be found without any previous presence of dead cells in very young branches and one-year-old seedlings in places which represent still intact cell centres such as in Fig. 155 *2p*. Therefore, the wound stimulus does not enter into the question here. We believe rather that all embryonic and mature cells are capable of forming gum as soon as certain processes of cell wall formation, or maturation, are suppressed. This prevention of the normal maturing of the cell wall can be caused very well by an increased supply of oxygen. This oxygen, however, can be directly atmospheric oxygen only in case of injury, but probably is only rarely actually such, being furnished rather by substances which carry oxygen as Grüss explains. Substances of this kind are ***present in the normal growth of trees.*** In an exudation of gum only ***an abnormal increase in the amount, or the length of action*** of these substances is involved[1]. This increase can take place because of wound stimulus. It can also be produced by different parasites and, finally, developed by inorganic poisons. In the latter connection, I would mention my experiments in introducing a weak oxalic acid solution under the bark of perfectly healthy cherry trees. In the course of the summer profuse streams of gum were produced which gradually ceased because of the dying out of the oxalic acid action and they did not continue, for example, in wounds which had received only distilled water instead of the oxalic acid.

In regard to the manner in which gum exudations can develop we will take as a basis the theories formulated by Grüss[2].

In his investigations, this scientist has come to the conclusion that the hemi-celluloses, Mannan, Galactan and Araban are deposited directly, or indirectly, as reserve substances. This takes place directly in the form of thickened cell walls in the endosperm of the seed (Phoenix, Phytelephas), or in the form of secondary thickening layers in libriform or wood parenchyma cells (different varieties of Astragalus, Prunus, Acacia, etc). They can be considered as indirect reserve substances if they compose the cell walls of cells containing starch, such as those in the endosperm of the Gramineae. The hemi-celluloses, Galactan and Araban, are changed by enzymes into the gums Galactin and Arabin and can migrate in the tissue even before they have been transformed into the sugars galactose and arabinose.

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[1] These substances are found in varying amounts in the tree according to the individual, the place of growth, the time of year, etc. This explains also the different results when the gum exudation is produced by injuries. Thus, for example, the youngest tips of the branches are not the ones most endangered in this, but the region in which the tissue elongates most, i. e. the region beneath the apex. In regard to the influence of the different sides of the tree and the seasons, I found in incisions made monthly that the late spring and the southern to western sides of the tree are most favorable for the development of gummosis.

[2] Loc. cit.

The oxygen carriers, which form gums, are now actually demonstrable as enzymes which are produced in the sprouting of the buds and, in fact, are present even before the diastase. The latter will then dissolve the hemicellulose, or other gums, as Grüss has proved for tragacanth.

If such enzymes are produced in excess or their anti-bodies develop in too small amounts, they hinder the normal development of the cell wall in embryonic cells, or begin the process of liquefaction in the complete cell of the mature wood, so that pathological gum centres are produced.

It is not at all improbable that an excess of oxalic acid, like the hydrolyzing sulfuric acid and other mineral acids, acts like the naturally formed ferments and produces thereby an exudation of gum. Such an increase of oxalic acid action can either be brought about by its more abundant formation, or through its lesser combination with calcium. Thus, for example, Mikosch[1] calls attention to the fact that almost no calcium oxalate crystals are found in the tissues involved in this transformation. It is evident from Benecke's works[2] that the content of these crystals depends upon the nutrition. He found in his cultures that the addition of nitrates favors the formation of calcium oxalate; that feeding with ammonia decreases this formation.

Among the parasites producing an exudation of gum, *Clasterosporium carpophilum* (Lév.) Aderh. (*Coryneum Beijerinckii* Oud.) should be named first of all. Nevertheless, a certain predisposition of the organ is necessary if the fungus should become effective. Aderhold[3] found in his inoculation experiments with leaves that red fungous spots occur without the formation of gums as, conversely, wounds with an abundant formation of gum could be found in the midribs of the leaves and in the cambium of branches in which the fungus was absent. The other parasites behave similarly; *Cytospora leucostoma; Monilia fructigena* and *M. cinerea, Botrytis cinerea* and many kinds of bacteria[4].

It is very possible that, in some of the parasites here named, oxalic acid is the poison produced by them which causes gummosis.

Before we take up the question of overcoming exudations of gum, it is necessary to turn our attention to the conditions under which the disease appears. Duhamel's theory is found most frequently confirmed in pomological literature. He thinks that cherry trees, which are planted in too strong soil, are most subject to the disease. We find this proved especially with the peach and cherry if clayey soil is understood by the term "strong soil." Exudations of gum are found less frequently on warm, porous soils which can be very rich. Further, we find exudations of gum abounding in

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1 Mikosch, K. Untersuchungen über die Entstehung des Kirschgummi. Sitzungsber. d. Akad. d. Wiss. Wien; cit. Bot. Centralbl. 1907, XXVIII, No. 27.

2 Benecke, W. Über Oxalsäurebildung in grünen Pflanzen. Bot. Zeit. 1903, Vol. LXI; cit. Bot. Centralbl. (Lotsy) 1903, No. 27, p. 16.

3 Aderhold, R. Über **Clasterosporium carpophilum** (Lév.) Aderh. und die Beziehungen desselben zum Gummifluss des Steinobstes. Arb. d. Biol. Abt. d. Kais. Gesundheitsamtes 1902, Vol. II, Part 5.

4 Ruhland, W. Über Arabinbildung durch Bakterien und deren Beziehung zum Gummi der Amygdalaceen. Ber. d. Deutsch. Bot. Ges. 1906, Part 7.

larger, unclosed wounds on the branches. In the same way, we find them occurring in specially young peach branches, of which the bark has been greatly injured by bruising or rubbing.

In my experiments, in which all the eyes were removed in the spring from a considerable number of cherry trees, an exudation of gum occurred with very few exceptions. In other experiments, in which the trunks had been peeled for a considerable distance, gummosis appeared in the bark near the upper girdling cuts, in which no new structures in the forms of callus had been formed. Finally, it is well known that great injury to the roots, or crown, in transplanting, as well as poor grafting, can give rise to the formation of gum.

All these injuries, in my opinion, do not act through necrobiosis but because of a simple wound stimulus which causes an excessive current of constructive materials to a spot where they cannot find normal utilization. There sets in at the same time, a hastened, new formation of cells, which becomes evident in the formation of the primordia of parenchymatous elements instead of prosenchymatous cells, as in all other processes of wound healing. Therefore, the activity of the new cell formation becomes excessively favored at a time when the constructive enzymes already prevail and wall-thickening as well as a deposition of reserve substances should begin. This prevalence of the enzymes of the youthful condition leads to the liquefaction of the diversely formed tissue groups. Such a displacement of the enzyme activity may be considered, in its effect, to be like a wave which continues to advance in the tree until it is stopped by some other constructive force. According to practical experience, such a halt is called by all those factors which condition a normal ripening of the wood and a precipitation, at the right time, of abundant quantities of reserve substances; porous soils, sunny open places, and a supply of calcium, avoidance of over-abundant nitrogen fertilization.

In treating wounds which are exuding gum, the use of *vinegar made from wine* is warmly recommended on all sides. I have had no personal experience with it.

EXUDATION OF GUM IN OTHER PLANTS.

EXUDATION OF GUM IN THE ACACIA.

Möller[1] maintains that the formation of Acacia gum depends upon changes similar to those of the cherry gum. He says very generally that the gum of the Acacia is always produced by a transformation of the cell wall, advancing from the outside inward. The walls of the parenchyma cells and the sieve tubes are the first ones to fall victim to the dissolution. (The collapsed sieve tubes form Wigand's *Horn prosenchyma.*) Möller observed the gum also as a product of the bark and found that it differs according to the zone in which it is produced. Gum arabic is produced by the dissolving

[1] Möller, Über die Entstehung des Acacien-Gummi. Sitzungsber. d. Akad. d. Wissenschaften. Wein. 1875, June issue.

of the inner bark while a less soluble form, similar to the cherry gum, occurs in the middle bark. This may well depend on the age of the affected tissue[1].

As one of the causes which give rise to the exudation of Senegal gum from *Acacia Verek,* Martins[2] mentions the action of dry desert winds which blow in the autumn and winter and cause the rupturing of the outer bark of the Acacia, which has become more furrowed because of the August and September winds. Other wounds, which result in the exudation of gum, are caused by a parasite which Martins calls *Loranthus senegalensis. Cryptogamic parasites* are also able to cause the wounds to remain open permanently and they thus exercise a stimulus for gum formation. *Coryneum gummiparum* Oud., which Oudemans observed as bud form of *Pleospora gummipara* Oud., acts just as *Coryneum Beijerinckii* does with the Amygdalaceae.

Gummy Exudation of the Bitter Orange[3].

Italian plantations of bitter oranges (*Citrus vulgaris*), lemons (*Citrus limonum*), and sweet orange trees (*Citrus Aurantium*) have suffered for many years from a disease which is constantly spreading, the "*Mal della gomma*" of the Italians, which causes such injuries that, according to Novellis[4], the Italian Department of Agriculture and Commerce has offered for years a premium of 25,000 lires for a proved means of curing it.

The disease begins with the appearance of black specks in the bark of the trunk and branches, especially near the points of bifurcation. These spots increase rapidly in size, until, after a little time, they become black places in the bark and split open A yellowish white liquid exudes from the surface, which gradually becomes denser in consistency and stickier, and finally hardens into yellow beads, or glaze-like coatings. The wood under the opening in the bark is brown and in a process of gummosis. If the gum is washed by rain on to other parts of the tree, new centres of disease are said to be produced. We find similar conditions also in regard to the acacia gum and it is not at all impossible that such cases exist. Like the mosaic disease of the tobacco, this may be explained as follows: The enzymatic bodies causing the formation of gum give the impetus for similar changes in predisposed healthy specimens and spread further like a wave.

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1 For the different relations of cellulose and gums to each other in different mucilaginous exudations, compare Tollens and Kirchner, Untersuchungen über den Pflanzenschleim; cit. Biedermann's Centralbl. 1875, II, p. 28. In regard to the formation of the sugar known as Galactose, from mucilaginous gums, soluble in water, when treated with dilute acid, see Gircaud, Etude comparative des gommes et des mucilages. Compt. rend. LXXX, p. 477. Peter Claëssen, Über Arabinose; cit. Jahresber. f. Agrikulturchemie, 1881, p. 88.

2 Martins, Sur un mode particulier d' excrétion de la gomme arabique produite par l' Acacia Verek du Sénégal. Compt. rend. 1875, I, p. 607. Kilіani, Über arabisches Gummi. Berl. chem. Ges. cit. Jahresber. f. Agrikulturchemie 1882, p. 88.

3 Savastano, L. Note di patologia arborea. Napoli 1907. The work contains various contributions on gummosis which we unfortunately cannot make use of at present and can only mention as in the last proof sheets.

4 Novellis, Ettore de, Il male della gomma degli agrumi; cit. Bot. Centralblatt 1880, p. 469.

The gummosis becomes fatal for the tree when the gum centres make up a greater part of the trunk circumference. According to Flühler[1] lemons suffer most and sour oranges least. Cuttings seem to retain the germs of the disease, and in the same way, grafted specimens seem to give a higher percentage of disease than seedlings which have remained ungrafted. Rich fertilization, heavy watering, clayey soils, increase the evil, which is said to increase also if cover crops, like pumpkins, beans, tomatoes, etc., are grown, which require heavy fertilization.

Judging by the material to which I have had access thus far, I consider the disease of Citrus fruits to be exactly the same phenomenon as the exudation of gum in the Amgydalaceae. I consider the excessive addition of fertilizers rich in nitrogen, to be one of the momentarily most frequent causes, which play a brief rôle also in Germany for the pitted fruits in nurseries.

Among the Italian authors, Peglion[2] shares the theory explained here. He calls attention to the fact that the cultivation of cover plants needing rich fertilization is injurious. Stable manure is not very suitable for Citrus. The fruit, to be sure, becomes large but remains thick-skinned and sour.

Blackleg of the Edible Chestnut.

According to Gibelli[3] this disease is characterized by the appearance of wilted yellow leaves and small fruit, poor in sugar. In young trees the base of the trunk dries up, the bark turns brown, and its tissues contain concretions of tannin as large as the head of a pin. Analyses show all the characteristics of plants growing poorly, i. e. a large ash content in proportion to the dry substance. In the ash is found a scarcity of potassium and phosphoric acid and a considerable increase of ferric oxid.

Because of the ball-like concretions, giving the tannin reaction, the disease seems to me to be related to the disease "Mal Nero" of the grapevine (see page 219). Comes[4] describes this form as gummosis. According to Cugini[5], this disease, because of which bud development is entirely retarded in the spring, or destroyed, is characterized by the appearance of black stripes and spots on the branches, petioles and ribs, tendrils, and stems of the clusters. The spots extend into the organs and, in fact, the trunk even to the heartwood. Besides this, the disease is characterized by the subsequent appearance of yellowish brown granules in the parenchymatous

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1 Flühler. Die Krankheit der Agrumen in Sicilien. Biedermann's Centralblatt 1874, p. 368.

2 Peglion, V. La concimazione e le malattie nella coltura degli agrumi. Boll. di Entomol. agrar., etc. 1901, in Bot. Jahresber. 1901. I, p. 479.

3 Gibelli, La Malattia del Castagno; cit. Bot. Jahresber. 1879, II, p. 375. Gibelli ed G. Antonielli, Sopra una nuova malattia dei Castagni, ibid. Cugini, Sopra una malattia che devasta i castagneti italiani, ibid.

4 Comes, Il Mal nero della vite. Portici 1882. Primi risultati degli esperimenti fatti per la cura della Gommosi o Mal nero della vite. Portici 1882. Sul preteso tannino scoperto nelle viti affette da Mal nero. Bot. Jahresber. 1882.

5 Cugini, Ricerche sul Mal nero della Vite. Bot. Centralbl. 1881, Vol. VIII, p. 147. Nuova indagini sul Mal nero della Vite. Bologna 1882. Il Mal nero della Vite. Firenze 1883.

elements of the trunk and branches. These granules often fill up the entire lumina of the cells and consist either of cellulose or of substances containing proteins. Cugini, who, morever, considers the phenomenon to be parasitic, also confirms the turning green of the blossoms and connects it with the disease. Differences of opinion prevail already among pathologists who have found parasites. Prillieux[1] considers *Roesleria hypogaea* as the cause, while Hartig[2] declares that this fungus is an accompanying phenomenon and that another, *Dematophora necatrix* is the real parasite.

Later investigations, especially those made by Pirotta[3], show that the above mentioned granules in the cells give the tannin reaction and arise directly from the starch grains. He found Rhizomorpha very frequently in the diseased roots, but not always; nevertheless, he does not consider this fact important enough to place the disease among fungus diseases. Comes showed that the granules in question do not represent accumulations of tannin but consist of a different ground substance (gum) which is only saturated with tannin.

Gummosis of the Fig Tree.

The disease of the fig tree (*Marciume del Fico*" of the Italians), which has been well known since the time of Theophrates, has been thoroughly studied by Savastano[4], who recognized it as gummosis.

This disease, to which old plants are more exposed than young ones, is found most markedly in the months of July, August and September when the leaves become yellow and fall, as does the fruit also. Although numerous fungi and even insects are found on the wilted and dead leaves (*Fumago salicina,* Tul, *Uredo Ficus,* Cast, *Phyllosticta Sycophila* Thüm., Sporodesmium, *Coccus caricae* Fab.), these parasites should not be considered causes of the disease. Usually there is no change in the trunk and branches, but a change does occur in the root, where the chief seat of the disease should be sought. In a highly advanced stage the roots seem blackish up to the crown. They sometimes split open, but oftener decay.

It is found in plants, raised from sprouts, that the seat of the disease may lie in the roots of the mother plant, from whence the further distribution takes place in all directions, but especially upward. The outermost layer is the most diseased; only at times is the innermost layer destroyed to any great extent. When the destruction reaches the crown, the plant dies absolutely.

When the disease appears, the cells and ducts are found filled with a substance which at first seems a lemon yellow and later a dark amber. At first the cell walls are covered with this and then the whole lumen becomes

[1] Prillieux, La pourridié des vignes de la Haute-Marne, produit par le Roesleria hypogaea. Paris 1882.

[2] Hartig, R. Rhizomorpha (Dematophora) necatrix. Der Wurzelpilz des Weinstocks. Untersuchungen aus dem forstbotanischen Institute zur München. 1883, III, p. 95. cit. Bot. Centralbl. 1883, No. 46 (Vol. XVI), p. 208.

[3] Pirotta, Primi studi sul Mal nero o Mal dello Spaceo neolle viti 1882; cit. Bot. Jahresber. 1882.

[4] Savastano, L. Il Marciume del Fico. Annuario della R. Scuola Sup. d'Agricult. Portici, Vol. III, fasc. V, 1884, con 4 tav. cromot. (nach brieflicher Mitteilung).

filled with it. The starch disappears with the increase of these masses. Savastano observed, even in seedlings, a production of gum centres at the point where the young roots passed into the trunk and branches. I found similar conditions in the sweet cherry, which externally showed no trace of disease.

Savastano found gummosis appearing also in the trunk and branches. He found a substance in its gum which seems to be similar to *"Olivile"* occurring in the *gummosis of the olive.* The gummosis of the trunk and branches starts in the gum glands found even in the roots of saplings. Only after the plants have become diseased with gummosis may the presence of Rhizomorpha be proved which other investigators have considered the causes of the disease. With the red discoloration of the walls, the parenchyma cells of the roots undergo a process of humifaction in which the specific weight of the tissue becomes less and less because the organic substances disappear.

A later work by Savastano[1] gives the results of comparative experiments with specimens of *Amygdalus Persica* and *Amygdalus communis, Prunus Cerasus, P. domestica, P. inititia, P. Mahaleb,* and *P. Armeniaca,* as well as *Citrus Aurantium, C. Limonum, C. vulgaris* and *C. nobilis,* and also of *Olea europaea* affected by gummosis. The results show that the gummosis of the plants named has much in common with that of *Ficus Carica.* In all, the formation of gum centres either takes place as a result of injury, or without any external cause. If the wound is overgrown quickly and completely, the gum formed dries up, as a rule, into brittle masses and remains uninjurious for the surrounding tissue. If, on the other hand, moisture is present on the wounded places, the gum remains soft and is easily carried over the surfaces surrounding the wounds, which also succumb to gummosis.

The Exudation of Manna.

In many plants, instead of gum, a hard, clear substance containing sugar comes from the bark of young trunks and branches, and is called *Manna* in trade. The liquefaction product contains Mannit which, when extracted with alcohol, can be obtained in fine white silky crystals, tasting slightly sweet, and may also be formed artificially from different sugars. Investigations of the Manna exudation were begun by Meyen[2]. According to him, the large amounts of Manna, which come from Italy, are obtained artificially from a kind of alder, the Manna Alder, by making incisions in the bark toward the end of July. From these incisions the Manna flows gradually as a thick,sweetish juice, hardening in the air.

Resinosis.

The exudation of resin (resinosis) is for conifers what exudation of gum is for the Amygdalaceae and the Manna exudation for the Oleaceae.

[1] Gummose caulinaire dans les Aurantiacées, Amygdalées, le Figuier, l'Olivier et noircissement du Noyer. Compt. rend. I, Decebre, 1884. Reprint.
[2] Pflanzenpathologie, p. 228.

It sometimes occurs in the wood and sometimes attacks the parenchyma and bast cells of the bark. The first stages of the disease are found in the resinosis of the wood; the mature condition consists in the formation of large quantities of uniform resin masses in cavities in the trunk and branches, which are usually called *resin boils.* It is well known that resin in the cell contents normally occurs in the form of drops or, as in the glue mats of many wood buds, in the intermediate lamellae of the cell wall, or finally, as in our pines and spruces, in definitely distributed, peculiar resin canals. The contents of many parenchyma cells near the resin canal show resin drops and starch grains, of which some not infrequently are provided with a resin coating. The immediate surroundings must necessarily furnish the substances which fill the large resin pockets. Whether this material is transported in the form of resin, as N. J. C. Müller[1] assumes, or in the form of some other compound and is only developed into resin where it is found as such, which theory Hanstein[2] is inclined to believe, is of little importance for our consideration. In this we have to maintain that the formation of considerable amounts of resin and gum is possible only through the transformation of a plastic substance, flowing toward those places where the liquefaction takes place, i. e. a positive loss of sap. To this it should be added for resinosis, as for gummosis, that the existing plant substance, in the form of wood and bark tissue and of starch grains, succumbs to liquefaction and that, in this way, considerable material is lost. According to investigations made by Karsten[3] and Wigand[4], the wood at first seems resiniferous, i. e. saturated with resin and balsam. In most of the cells of this saturated tissue, the resin appears as a wall coating, or as drops which have spread together until the cells seem completely filled with the mass. The walls of the cells, originally thick, become thinner and thinner in the same degree as the amount of resin increases within the cell, until, finally, only a fine outline is left, which is gradually lost in the mass of resin.

As in gum exudation, the medullary rays also seem to be longer resistent, since they are clearly seen to extend into the uniform resin mass of the dissolved wood cells surrounding them. For complete analogy in the two processes, there is lacking only the proof that, in the exudation of resin, an abnormal wood parenchyma is formed, which undergoes absolute resinosis.

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1 Müller (Über die Verteilung der Harze usw. in Pringsheim's Jahrb. f. wiss. Bot. 1866—67, p. 387 ff) says the great amount of resin in the resin ducts cannot have reached that place except by penetrating many cell walls. He finds the cell walls to be permeable for resin. Thin cross sections of pine wood left lying for some time in water showed that all the resin in the cell walls has been replaced by water.

2 Hanstein (Über die Organe der Harz- and Schleimabsonderung in dem Laubknospen. Bot. Zeit., 1868, No. 33 ff.) speaks of the occurrence of resin first in the grooves of secretion cells as small bands between the cuticle and the cellulose membrane. This is undoubtedly an important reason for assuming that "the resin, which occurs in the form of intermediate wall layers, first assumes its real character after it has passed through the cell wall in another form and been deposited as an intermediate layer."

3 Karsten, H. Über die Entstehung des Harzes, Wachses, Gummis und Schleims durch die assimilierende Tätigkeit der Zellmembranen. Bot. Zeit. 1857, p. 316.

4 Wigand, Über die Desorganisation der Pflanzenzelle. Pringsheim's Jahrb. f. wiss. Bot. Vol. III, p. 165.

It has often been observed that the starch grains in resinosis succumb to liquefaction just as in gummosis. Starch certainly furnishes a large part of the resin in the exudation. Wiesner[1] states, for example, that resin bodies exist within the medullary ray cells of foliage trees and possess the structure of the starch grains. These rarely turn blue with the use of pure iodine but do so more often with iodine and sulfuric acid. With the use of ammoniacal cuprous acid they give the cellulose reaction; they react to ferric chlorid like tannin. Wiesner, therefore, concludes from his investigations that a large amount of the resin, occurring in nature, arises from starch grains themselves, or from starch grains which have been changed into tannin. He considers the tannin to be a connecting link between the cellulose and resin.

We find in Nottberg's[2] very thorough work on resin pockets the proof that even in the exudation of resin an abnormal parenchyma wood is formed which succumbs to resinosis and liquefaction. Nottberg proves that, as a result of any injury, whatever, which extends to the cambium, this responds with the production of a "tracheidal parenchyma" which gradually passes over again into the normal tracheids. The tracheids of the sap wood which, as a result of the injury, come into contact with the outer world, stop up their lumina with a mass resembling wound gum, which is insoluble in alcohol but dissolves after treatment with Schultz's mixture. Usually resinosis occurs at the same time in the wood body. The different cells of the diseased parenchyma immediately after their production begin to form resin internally (resin cells). The membranes of the new cells of the tracheidal parenchyma liquefy very early. The unthickened elements, on the other hand, as long as they are retained, constantly show only the cellulose reaction. In the resin cells a definite layer may be recognized in which the resin is formed (resinogenous layer, Fig. 157). Nottberg, from whose book the figure is taken, leaves undecided what this resinogenous layer is; "a developmental product of the membrane, or of the cyptoplasm."

Fig. 157. Cells of the tracheidal parenchyma of Pinus Strobus with the resiniferous layer rsg; ht resin drops. (After Nottberg.)

The pathological formation of resin may be considered the most extensive process of liquefaction at present known in the vegetable kingdom. It existed in the tertiary period as well as now, for Conwentz states in his monograph on the Baltic Amber trees (*Pinus succinifera*, Conw.), which has excellent illustrations, "there was scarcely one healthy tree in the whole

[1] Sitzungsbericht d. Akad D. Wissensch. zu Wien, Vol. 51.

[2] Nottberg, P. Experimentale Untersuchungen über die Entstehung von Harzgallen und verwandter Gebilde bei unseren Abietineen. Zeitsch. f. Pflanzenkr. 1897, p. 133 ff. Hier auch weitere Literatur.

amber forest; the pathological condition was the rule; the normal one, the exception."[1] We cannot better present the processes of resinosis than by showing copies of the amber sections which Conwentz has reproduced (Figs. 158-161).

Just as at present, we find that the process of resinosis began as follows: —resinosis and liquefaction of the membranes, and finally of the whole cell

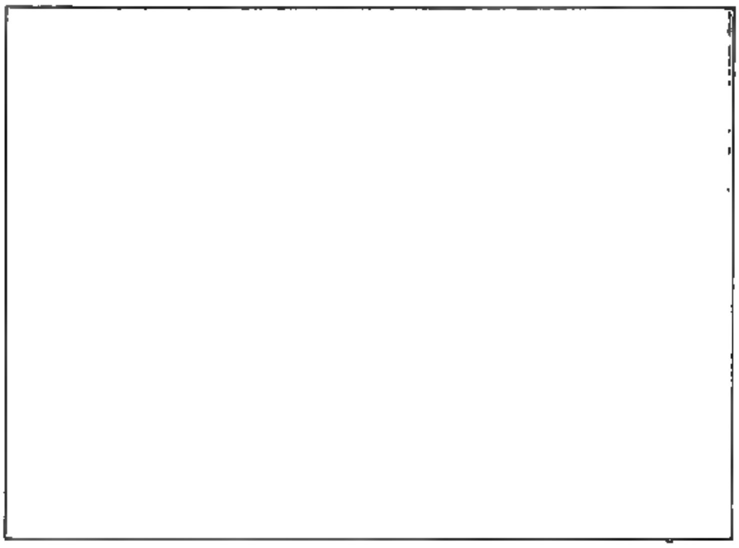

Fig. 158. Process of turning to resin, beginning with the formation of a lysigenous resin canal in the wood. 205.1. (After Conwentz.)

Fig. 159. Horizontal section. In the summer wood of an annual ring is a group of abnormal wood parenchyma cells (P). 56:1: The holes in the tissue were produced in sectioning. (After Conwentz.)

together with its contents, set in in different groups between two medullary rays (Fig. 158). No anatomically different tissue is necessarily present here, but, in the majority of cases, such an one is present and in fact in the form of wood parenchyma which develops in tangential strips. Conwentz

[1] Conwentz, Monographie der baltischen Bernsteinbäume, Danzig, 1890, p. 145.

describes these strips (Fig. 159) in the summer wood. Up to the present I have found them predominantly in the spring wood of our trees so that a new annual ring begins at once with the abnormal wood, or after only a few cell rows. I trace the production of these strips back to a transitory weakening of the bark tension (see Frost Phenomena). This abnormal wood parenchyma is shown in a complete stage of resinosis in Fig. 160. Masses of resin, or rather amber, already produced, can push out the bark away from the oldest part of the trunk. Conwentz found such bark elements in so good a state of preservation that he still could prove their nuclei. (Fig. 161.)

Nottberg found, in the liquefaction of the solid tracheid parenchyma, that the tertiary membrane was retained longest; this may be observed also in the spreading of the gum centres of the cherry.

Fig 160. Horizontal section with abnormal parenchyma wood (P), which has begun to turn to sugar. The abnormal tissue lies in the summer wood. J is the edge of the annual ring. 210:1. (After Conwentz.)

Nottberg distinguished good and evil wounds according to whether the wound heals at once or affects the surrounding tissue. It should still be noted that the trees, of which the wood normally has no resin canals at all (the white fir), are found to abound in resin canals after injury, especially in the edges of the callus. These investigations have been confirmed by v. Faber[1], who also emphasizes the fact that the pathological resin canals are formed schizogenously. They anastomose in a tangential plane and form a connected network, while their open ends extend into the wound. Above these the resin canals are more abundant and longer than they are below them.

In opposition to the statements that the cause of resinosis may always be sought in wounds, I must maintain, as in gummosis, that the processes of liquefaction can also arise autogenously, without wound stimulus. I have observed this in seedlings of pines from heavily manured nurseries.

[1] v. Faber, E. V. Experimentaluntersuchungen über die Entstehung d. Harzflusses bei Abietineen. Dissertation. Bern 1901.

and found similar cases likewise in older plants of *Pseudotsuga Douglasi, Abies Fraseri* and *Abies concolor,* which showed swellings of the bark. These could be proved to be a lysigenous widening of schizogenous resin canals. The trees stood on moist, marshy soil which had been heavily manured at intervals of two or three years.

Recently, I have had opportunity to observe resinosis as a constitutional disease, i. e. as the manifestation, even in old trees, of a tendency throughout the whole plant body, to form resin excessively. I have distinguished this universal disease, as *"chronic resinosis,"* from the *"acute resinosis"* produced locally as a result of wound stimulus, and remaining localized, which is connected with the exudation of profuse amounts of resin[1]. Accordingly, in the future, a chronic and an acute gummosis would have to be distinguished from one another and in the latter, the treatment of the wounds with vinegar, already recommended, might be successful.

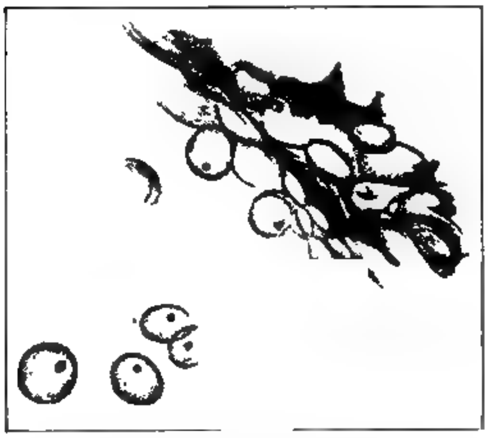

Fig. 161 Group of parenchyma cells from the outer bark which has been completely separated from the central wood cylinder by the turning to resin of an annular, abnormal zone of wood parenchyma. The nuclei may still be discerned in the bark cells. (After Conwentz.)

Formation of Resin in Dicotyledonous Plants.

The production of resin and gum resin in dicotyledonous plants is found to be parallel to the processes described in the preceding section. Svendsen[2] found that the gum resins of Styrax, Liquidamber, Toluifera, etc., are pathological products, produced as a result of injury. After every injury, which extends as far as the cambium, wound wood is formed which is distinguished by its tracheidal, parenchymatous character and which gradually passes over again into normal wood. The processes, therefore, are everywhere the same, just as was described and illustrated under injuries due to the frost. The wound stimulus makes itself felt in the old wood by a stoppage of the ducts with tyloses, or the closing of them by Bassorin. The new wood, which is formed about the wound and at first is parenchymatous, has resin canals produced schizogenously; and widening lysigenously. The resinosis thus attacks the wood parenchyma, with the exception of considerable parts of the medullary rays, and continues later in the bark, where it becomes noticeable within the bark rays; a fact which should be emphasized. In dicotyledons, as in conifers, the patho-

[1] Landwirtschaftliche Jahrbücher 1908.

[2] Svendsen, Carl Johan. Über den Harzfluss bei den Dicotylen, speziell bei Styrax, Canarium, Shorea, Toluifera und Liquidambar. Archif for Mathematik og Naturvidenskab. Kristania 1905, Vol. XXVI, No. 18.

logical formation of resin is perfectly independent of the presence of normal resin canals. The conditions seem to be more complicated in Peru and Tolu Balsam.

Therefore, so far as we can examine the pathological formation of resin, it corresponds perfectly to gummosis and, therefore, the same theories, which we have expressed earlier, hold good for it. It is not the wound stimulus in itself which causes the liquefaction of the solid tissues, but enzymatic actions, which we cannot determine at present, manifested in the result that scattered tissue groups fail to develop normally and dissolve because of oxydation. These processes can be introduced by wounds but also arise from a changed nutrition. They are dependent upon a definite developmental phase, i. e. the time of the sprouting of the trees. Centres of liquefaction, already existing, may be increased by the transmission of their enzymes to normal, permanent tissue.

Supplementarily, we will cite a number of phenomena, some of which belong directly to degeneration due to gummosis, and others belong here because we conceive them to be the results of enzymatic disturbances of equilibrium.

Analogous to the exudation of gum is the exudation of transparent gummy masses in *Eleagnus canadensis,* occurring especially about the edges of wounds. Frank has described it more exactly. I found the formation of gum in palms, cucumbers, cacti, and hyacinth bulbs[1].

I assume an enzymatic disturbance in the *heart rot* and the *black ring condition of the horse radish*[2], the *glassiness* of cacti, orchids, carnations, etc. Conditions of weakness are thus created which render the plant susceptible to parasitic attacks. Wood has referred to this point with especial distinctness: "I called special attention to the fact that plants rich in oxidizing enzymes were more sensitive to unfavorable conditions of temperature, moisture and especially to insect enemies than plants poor in these enzmyes."*

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1 According to Comes, the "Brusca of the Olive" is a decided gummosis.
2 s. Zeitschr. f. Pflkr. 1899, p. 132.
* Loc. cit., p. 22.

SECTION IV.

EFFECTS OF INJURIOUS GASES AND LIQUIDS.

CHAPTER XVI.

THE GASES IN SMOKE.

Sulfurous Acids.

The injuries to vegetation due to the gases in smoke have become so numerous and varied, with the constantly increasing spread of textile industries, that the study of them begins to form a separate branch of pathology, in which chemistry and botany are equally concerned. It is thus evident that this branch of science demands special attention. The subject has been most extensively treated in Haselhoff and Lindau's book[1] and later in that of Wieler[2]. Because of the abundance of material on injuries from smoke we can here merely refer to these works and treat more thoroughly only the points less fully taken up in them.

For a long time, scientists were in doubt as to which element in the smoke was the injurious one, until the investigations of Morren[3], Stockhardt[4] and especially v. Schröder[5] proved it to be the sulfurous acid. The metallic poisons, like arsenic, zinc and lead, to which especial attention was formerly paid in studying the injuries due to the smoke of smelting houses, have been proved experimentally to be less injurious to our cultivated plants, while a very small addition of sulfurous acid to the air is able to bring about the death of the plants under experimentation. How small this addition need be is shown by Morren's[6] observations. He could perceive the characteristic indications of destruction in the leaves even when the air contained

[1] Haselhoff, E., und Lindau, G., Die Beschädigung der Vegetation durch Rauch. Berlin 1903, Bornträger, 412 pages, with 217 illustrations.

[2] Wieler, A. Untersuchungen über die Einwirkung schwefliger Säure auf die Pflanzen. Berlin 1905, Gbr. Bornträger.

[3] Récherches experimentales pour déterminer l'influence de certains gaz industriels, spécialement du gaz acide sulfureux, sur la végétation. Extracted from the Report of the International Horticultural Exhition, etc. London 1866.

[4] Untersuchungen über die schädliche Einwirkung des Hütten- u. Steinkohlenrauches auf das Wachstum der Pflanzen. Tharandter forstl. Jahrb., Vol. 21, Part 3.

[5] Die Einwirkung der schwefligen Säure auf den Pflanzen, in Landw. Versuchsstationen 1872.

[6] Loc. cit., page 224.

only 1-50,000 of its volume in sulfurous acid. Schröder states[1] that one one-millionth will prove injurious if allowed to act for some time. Such slight amounts are certainly present in many kinds of smoke, formed by the oxidation of hard coal, which contains sulfur. Moreover, since sulfur in the form of iron sulfid is an abundant element in hard coal, it may be assumed that, as Morren says, we establish a poison centre for plants with every chimney we erect.

Yet, at any rate, we should not carry this anxiety too far. The experiments, proving the injuriousness of such small amounts of gas, were made in a space enclosed by a bell jar and the gas usually acted for several hours.

This corresponds in everyday life only to the constitution of the air in the immediate proximity of an industrial establishment, such as smelting house, coke oven, etc., in a narrow valley where the smoke lies day and night in great masses above the vegetation. In the majority of cases the motion of the air, and especially wind, together with the characteristic oxidation of sulfurous acid into sulfuric acid when in contact with moisture, serve as a protection against the most extreme action of the poison, and against immediate death. In any case, however, it would be well, in regions where hard coal or peat[2] is burned, to choose for industries producing a great deal of smoke, such positions as are removed as far as possible from large plantations, especially from tracts of trees.

The gaseous products, from burning hard coal *free from sulfur* are not injurious to vegetation[3]. If the coal, however, contains some sulfur and gives it off into the air as sulfurous acid, it will be taken up by the leaf-organs of the conifers and deciduous trees. According to v. Schröder the greater part is retained in these organs and only a small amount is carried into the wood of the plant. The experiments made by Freitag[4] directly in this connection indicate that we shall have to consider the leaves as the main organs for taking up the poison. Yet all leaves do not take up equal amounts of the poison offered them; in this, conifers differ markedly from deciduous trees. Under similar external conditions, with equally large leaf surfaces, the former take up less sulfurous acid than do the latter. Yet it can not be said that a plant suffers more when it has taken up a greater amount of gas. The power of resistance depends rather upon the special organization of the plant. In this connection, the supposition is pertinent that the anatomy, especially the number of stomata, may be determinative for the sensitiveness of a plant. This supposition, however, which has been repeatedly expressed by Morren, has proved to be erroneous, since Schröder has

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1 Schröder, J. v., und Reuss, C. Die Beschädigung der Vegetation durch Rauch usw. Berlin 1883, P. Parey.

2 According to Stöckhardt the smoke from lignite and peat is also injurious, for this fuel contains sulfate of silica. The smoke of lime kilns is less injurious because the lime retains the sulfurous acid form, just as in brick ovens the magnesia content frequently present in the clay acts favorably because of the retention of the sulfurous acid. Chemischer Ackersmann 1872, Part II, p. 111 ff.

3 Proved for plum and pear trees.

4 Mitteilung der landwirtsch. Akad. Poppelsdorf. Vol. II, 1869, p. 34 cit. bei Schröder loc. cit., p. 321.

found that the sulfurous acid is taken up not only by the stomata but uniformly by the entire upper surface of the leaf. He found that just as much gas was taken up by the upper side, free from stomata, as by the underside which abounds in these respiratory organs only the action of the gas which had penetrated the underside was much more rapid and energetic. This is explained by the fact that sulfurous acid is greedily absorbed by water and oxidizes easily in contact with it. Now, since the loss of water from the leaf into the air takes place especially through the porous underside which abounds in stomata, the action of the gas manifests itself so much the more here. If the water in the micellar interstices of the cell-walls is combined with the acid in greater amounts than can be supplied to the walls, they become deficient in water and finally dry up, thereby losing their capacity to conduct water.

Thus only those cell bodies will remain well supplied with water and will retain their normal color, which lie directly against the rapidly conducting tissue of the vascular bundles while the dry part, lying between the vascular bundles (the leaf veins) takes on a faded, brownish color. This phenomenon of *bright green venation* in a faded leaf mass has been taken as a characteristic point for recognizing leaf poisoning from sulfurous acid. Hartig[1] maintained that the *red coloration* of the guard cells of the stomata in conifers is a positive characteristic of injury due to acid. This statement, however, was immediately refuted by other observers. Wieler[2] and Sorauer[3] have proved that slow death, under the influence of light and with the action of very different factors causes a red coloration. Directly in connection with this characteristic, apparent to the naked eye, is the decreased water evaporation from poisoned leaves, as found by v. Schröder in weighing experiments. The amount of the transpiration may be used, however, as the expression of the amount of production and thus it may be concluded here that the leaf-assimilation is less. The general effect of the poisoning on the plant body will, therefore, resemble permature defoliation and, in fact, the action sets in the more quickly the greater the amount of sulfurous acid present, the drier the air, the higher the temperature and the stronger the illumination, which are the factors inciting the leaf to more intensive activity. Because of this fact, which has been determined experimentally, the supposition that the smoke from smelting works and from hard coal will act less vigorously at night than during the day is pertinent, and we will find later that it is confirmed.

Caution is necessary, however, when forming one's judgment from the characteristic of green venation and dried middle fields. Almost all injurious atmospheric effects express themselves in such a way that the parts of a leaf lying furthest from the water-conducting ribs, namely, the fields between

1 Hartig, Rob. Über die Einwirkung des Hütten- und Steinkohlenrauches auf die Gesundheit der Nadelholzbäume. München 1896, Rieger'sche Buchhandl.

2 Wieler, Über unsichtbare Rauchschäden bei Nadelbäumen. Zeitschrift für Forst. u Jagdwesen 1897, Sept.

3 Sorauer, P. Über die Rotfärbung von Spaltöffnungen bei Picea. Notizbl. d. Bot. Gart. Berlin 1896, No. 16.

these ribs (intercostal fields), suffer earliest and most extensively from frost, sunburn, etc. With the action of the acids in smoke, however, the boundaries between the dead and healthy tissues are as sharp as usual, while with the action of atmospheric factors they are less distinct because of the many transitional stages.

The appearance of the injury in decidedly smoky districts also differs because, besides sulfurous acid others, such as sulfuric acid, hydrochloric acid, hydrofluoric acid, etc., become effective. The action of these acids strongly soluble in water (hygrophilous) is restricted, however, to the immediate surroundings of the centre of production, where they act at any rate much more intensively and kill the tissue rapidly, while sulfurous acid, distributed in a gaseous form over wide districts, is usually breathed in by the plant slowly but permanently. The former effect, appearing rapidly and eating into the tissue, is distinguished as *"acute"* from the phenomenon of a slow poisoning which is termed *"chronic injury from smoke."* Of course, the latter must have made itself felt inside the plant before the external characteristics appeared. The chlorophyll apparatus is changed (as has been proved by Wislicenus[1] with the spectroscope and by Sorauer[2] with the microscope) even if the plants still appear perfectly normal. In this case an *"invisible injury from smoke"* is spoken of. Naturally such disturbances can be averted very easily and the plant, as has been found, is in a position to cure itself after the cessation of a weaker action of smoke.

Such cases will also occur in forestry if changes in local conditions take place which divert a stream of smoke or dilute it to the point of uninjuriousness. Wislicenus[3], to whom we owe recent especially thorough, conscientious investigations, states that the point of uninjuriousness is 0.0005 per cent. of the volume.

He emphasizes the fact that, aside from the extreme individual difference in sensitiveness, the stage of development of the plant is of decisive significance. The time when the new leaves and needles unfold is the most critical; the plants suffer most then, because the cuticular covering of the epidermis is still insufficiently developed. The above-mentioned influence of light, which promotes injury and was observed by v. Schröder and Hartig, has been tested experimentally by Wislicenus[4], who found that visible injuries did not appear in young spruces in the dark and in winter, although an increase of the sulfur content could be proved. Ramann and Sorauer[5] have also observed that the amount of demonstrable sulfur in an organ is not determinative for the degree of injury and Count zu Leiningen[6] calls

[1] Wislicenus, Resistenz der Fichte gegen saure Rauchgase bei ruhender und tätiger Assimilation. Tharandter Forstl. Jahrbücher 1898, Sept.

[2] Sorauer, P., u Ramann. E. Sogenannte unsichtbare Rauchbeschädigungen Bot. Centralbl. 1899, Vol. LXXX. See also Brizi in Zeitsch. f. Pflanzenkrankh. 1904, p. 160.

[3] Wislicenus, H. Massnahmen gegen die Ausbreitung von Hüttenrauchschäden im Walde. Referat 5 der Sekton VIII d. Internat. landw. Kongresses in Wein 1907.

[4] Tharandter Forstl. Jahrbücher 1898, p. 152.

[5] Loc. cit.

[6] Graf zu Leiningen, W., Licht und Schattenblätter der Buche. Naturwiss. Z. f. Landw. u Forstw. III. Jahrg. Part 5.

attention to a factor which is of decisive importance in making tests as to the estimate of injuries due to acid viz., to the very different amounts of sulfur and chlorin in *shade leaves* as contrasted with *sun leaves*. He found in the beech in one square meter of leaf substances:—

	in sun leaves	in shade leaves
SO_3	0.2730 g.	0.3004 g.
Cl	0.0190 g.	0.0347 g.

Therefore, the less abundant the production of organic substances is the relatively higher becomes the content of sulfuric acid and chlorin. The statements of Wislicenus express the same: "A poorer soil quality, that is, soil constitution of less value physically and chemically, soils specifically unsuitable for the plant genus or primarily insufficient, excessive, or abnormally varying water content of the soil create a *predisposition to disease from smoke;* among them the chief factor is the lack of water."

The fact that the conditions in a forest become different because of the falling of the needles and the dying of the branches, indeed, that the appearance of deciduous trees is changed, that the trunks become almost entirely free from lichens[1], and that the bark of the trunks of beeches takes on a peculiar grey tone, may be mentioned only in passing. The statements of v. Schröder and Reuss point directly to the change in soil constitution. They still say that an accumulation of undecayed needles is formed under spruces chronically injured by smoke and a complete absence of all living vegetation is noticeable as far as the dropping from the tree extends. This indicates a *"poisoning of the soil."* This is proved by Reuss' experiments, in which he carried soil from a smoke filled region into a zone free from smoke and set out plants in it. After three years, the loss in 1 to 2-year-old seedlings of the ash amounted to 100 per cent., of the maple 92 per cent., of the beech 72 per cent., of the spruce and pine 8 per cent., and of the oak, none.

Wieler[2] has now taken in hand especially the question of soil poisoning and has proved that under certain circumstances in smoky regions with a continued out-pouring of smoke, sulfurous acid could be proved to a depth of 30 cm. and had, therefore, not been changed into sulfuric acid. The latter will also remain uninjurious only so long as it can combine with bases. If these bases are used up in neutralization and are washed away by rain the *humic acid* present finds no possibility of combination. In fact, all the soil tests made by Wieler, from regions injured by smoke, showed great amounts of humic acid. Calcium, which could have combined with the humic acid produced is, therefore, not present in these soils. The other bases, however, with which the humic acid forms soluble compounds (magnesium and iron) must have disappeared from the soil. Thereby, naturally, the absorptive power of the soil becomes poorer for other mineral nutritive substances. This refers also to the alkali forming soluble compounds of

1 Lindau, loc. cit., p. 120.
2 Wieler, Neuere Untersuchungen, etc., p. 314.

humic acid which likewise pass into the subsoil. The lack of calcium makes more difficult the decomposition of the humus substances and the nitrogen enclosed in them remains inaccessible to the plants. At times the bacterial flora is scanty in acid soils. The free sulfurous and sulfuric acids may act injuriously also on animal organisms such as earth worms. Soils in smoky localities will become impoverished or poisoned by all these factors.

Wieler ascribes the death of plants and especially chronic injuries to the scantier absorption capacity of soil, which has been poisoned and weakened by sulfuric acid or also by hydrochloric acid, but certainly goes too far into this, since all experiments show that the direct contact with the smoke forms the chief cause of death of the aërial organs: also comparative chemical analyses of the foliage and of the soil from which it is produced, do not always indicate an impoverishment of the supply of bases, but at times, in fact, a strong increase of calcium and magnesium[1] Yet, nevertheless, this aspect of the effect of acid smoke remains of the greatest importance and the attention of practical workers should be directed to periodically repeated application of calcium to the soil.

We must refer to special works for the influence of currents of air and their constitution, especially their water content, as well as for proving acids in the air and the regulations for overcoming injuries due to smoke. We would like to mention only that Ost[2] has given a simple method for determining the amount of sulfuric acid in the air. He saturated small pieces of cloth with corrosive barite and dried them. He then hung them in exposed positions in the places where the experiments were being made and after a certain time investigated their sulfuric acid content. By this method even pure mountain air showed a certain amount of sulfuric acid as its normal mixture, which must increase significantly in the neighborhood of villages. We have found recently in a lecture by the chief forestry commissioner, Reuss[3], a summary of the requirements of foresters for the protection of the forest against smoke. He indicates the necessity of forming indemnification societies in regions where many factories are placed close together.

The fact should not be left unconsidered that when damages are demanded the objection is raised not infrequently by the injuring smelters and factories that eating by insects is the chief cause. In this connection, Gerlach[4] calls attention to the fact that spruce plantations, diseased by smoke, are preferred by the resin weevil. Not only *Pissodes Herciniae* and *P. scabricollis,* but also other insects, like *Grapholithia pactolana* and *G. Chermes* increase to a devastating degree in forests injured by smoke.

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[1] Die landwirtschaftliche Versuchsstation in Münster i. W. Denkschrift von J. König. Münster 1896, p. 191 ff.

[2] Ost, H. Die Verbreitung der Schwefelsäure in der Atmosphäre. Die chem. Industrie 1900; cit. Zeitschr. f. Pflanzenkrankh. 1901, p. 248.

[3] Reuss, Karl. Massnahmen gegen die Ausbreitung von Hüttenrauchschäden im Walde. Internat. Landw. Kongress zu Wein 1907, Section 8, Ref. 5.

[4] Gerlach, Beobachtungen und Erfahrungen über charakteristische Beweismittel uzw. Merkmale von Rauchschäden. Österr. Forst- u. Jagdzeitung; cit. Bot., Centralbl. 1907, No. 40, p. 360.

HYDROCHLORIC ACID AND CHLORIN.

Besides sulfur, hard coal also contains chlorin in the form of sodium chlorid[1]. The chlorin content varies between 0.1 to 2.0 per cent. Leadbetter found in hard coal 0.009 to 0.028 per cent. of chlorin[2]. This, however, could not be proved in the ash and must, therefore, have been forced out with the volatile substances. Meinecke has also directly proved the presence of chlorin in the gases of blast furnaces[3] and Smith[4] calls attention to the chlorin content of rain water in regions where hard coal is burned in considerable amounts. According to these statements, therefore, we must not consider any single injurious factor in the smoke of hard coal but different combinations of several factors. The difference will depend, on the one hand, on the composition of the coal and, on the other hand, on its use industrially.

Because of the rapid formation of hydrochloric acid from chlorin in the presence of moisture and light both these factors must be treated together. In connection with sulfuric acid, mention has already been made of the impoverishment taking place possibly from the continued action of hydrochloric acid in the soil. The action of direct solutions of chlorin alkalies will be mentioned in connection with cooking salt. The action on the plant varies according to its species, the season of the year, or the place and individual development. In general, this results in a bleaching and drying of the leaf edges, or also of the intercostal fields in which chlorin vapor acts more quickly than does hydrochloric gas. In contrast to sulfurous acid, however, dry leaf edges preponderate here. It was observed in the experiments made by Ramann and Sorauer (see Sulfurous Acid) that spruces sprinkled with water absorbed, on an average, less chlorin than plants not moistened.

The studies on the changes in anatomy have up to the present led to contradictory results. Thus Lindau[5] observed in Abies an alteration only at and near the stomata, while Kinderman[6] confirms the investigations of Leitgeb and Molisch, that the guard cells possess the greatest power of resistance to injurious factors (among others, acids), which probably arises from a special constitution of the cytoplasm.

Because of the uncertainty of results up to the present time, I will repeat here briefly the results of my own studies on grain and spruce[7]. At first the heavy general falling off in reproduction which the plants undergo, because of the hydrochloric vapors, and which manifests itself in the quantitative proportions and the formation of the grain, has been found to be very

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1 Hasenclever, Über die Beschädigung der Vegetation durch saure Gase. 1879, p. 9. Berlin, Springer.

2 Chemical News 1860, No. 46.

3 Dingler's Journal 1875, p. 217.

4 Bericht über die Entwicklung der chem. Industrie von A. W. Hofman, 1875.

5 Loc. cit., p. 244.

6 Kindermann, V. Über die auffallende Widerstandskraft der Schliesszellen gegen schädliche Einflüsse; cit. Just. Bot. Jahresber. 1902, II, p. 653.

7 Sorauer, P. Beitrag zur anatomischen Analyse rauchbeschädigter Pflanzen. Landwirtsch. Jahrbücher 1904, p. 587.

pronounced; this confirms the investigations of Wieler and Hartleb[1]. Such an effect can occur without an indication of a disturbance in growth by any striking external characteristics. As a rule, however, this disturbance in growth is accompanied by a discoloration of the chloroplasts and their subsequent balling. There then follows a contraction of the primordial sack and a shrivelling of the chlorophyll grains. The leaf thus injured may still at times live out its life normally, depending upon the intensity and length of action of the chlorin. Usually, however, it dies prematurely, in part or entirely. In the latter case, principally the leaf parts die, for which, because of their position and the lesser development of mesophyll and vascular bundles, the supply of water is acquired less easily and is smaller; these are the tips and edges of the leaf. Therefore, we find dry, discolored leaf tips in grain and narrow dry outlines on both sides of the lower part of the leaf surface which still remains green. As a result of *rapid death,* a *comparatively important* condition is found in the cell content of the dead parts. The drying with the retention of air in the tissue is connected with a shrivelling of the cells; yet in such a way that the walls of each cell do not touch one another. The natural process of drying, on the other hand, which occurs only after *complete impoverishment of the cell content,* is characterized by the entire collapse of the mesophyll cells, in which the upper wall falls against the lower wall and the whole flesh of the leaf, formerly green, represents a pale straw colored strip of dense tissue with curving walls lying upon one another in layers. The collapse of the cells in different varieties of grain, with the exception of barley, extends almost entirely in the mesophyll during the natural process of drying, while the epidermal cells retain approximately their normal height. In barley (characterized by practical workers as "soft"), the epidermal cells also collapse in a natural death. But in this, some of the widest cells of the upper surface form an outward fold. In a cross-section through the dead leaf this appears as a conical protuberance resembling a hair and gives the whole cross-section the appearance of a thin, knotty spiny cord.

Because of the importance of distinguishing a leaf which has died a natural death from one destroyed prematurely by acid gases, we will illustrate a leaf injured by acids and one which has died normally. Fig 162 *1* is the cross-section through the edge of an oat leaf dried by hydrochloric acid, or chlorin vapor. It is seen that the tissue has shrivelled greatly, especially between the ribs (the intercostal fields) *without the mesophyll having had time to become empty.* The cell contents appear a dirty green to a brownish green color and variously contracted. The walls of the bast layers at the angles of the leaf (*B*) and below the vascular bundles (*b*) like the epidermis are colored a *reddish yellow* to a *brownish yellow* and the epidermal cells in places (*s*) are so dried that the upper wall touches the lower wall. Fig. 162, *2* is a magnified cell group from 162, *1*, showing the still abundant cell content.

[1] Wieler, A., and Hartleb, R. Über Einwirkung der Salzsäure auf die Assimilation der Pflanzen. Ber. d. Deutsch. Bot. Ges. 1900, p. 348.

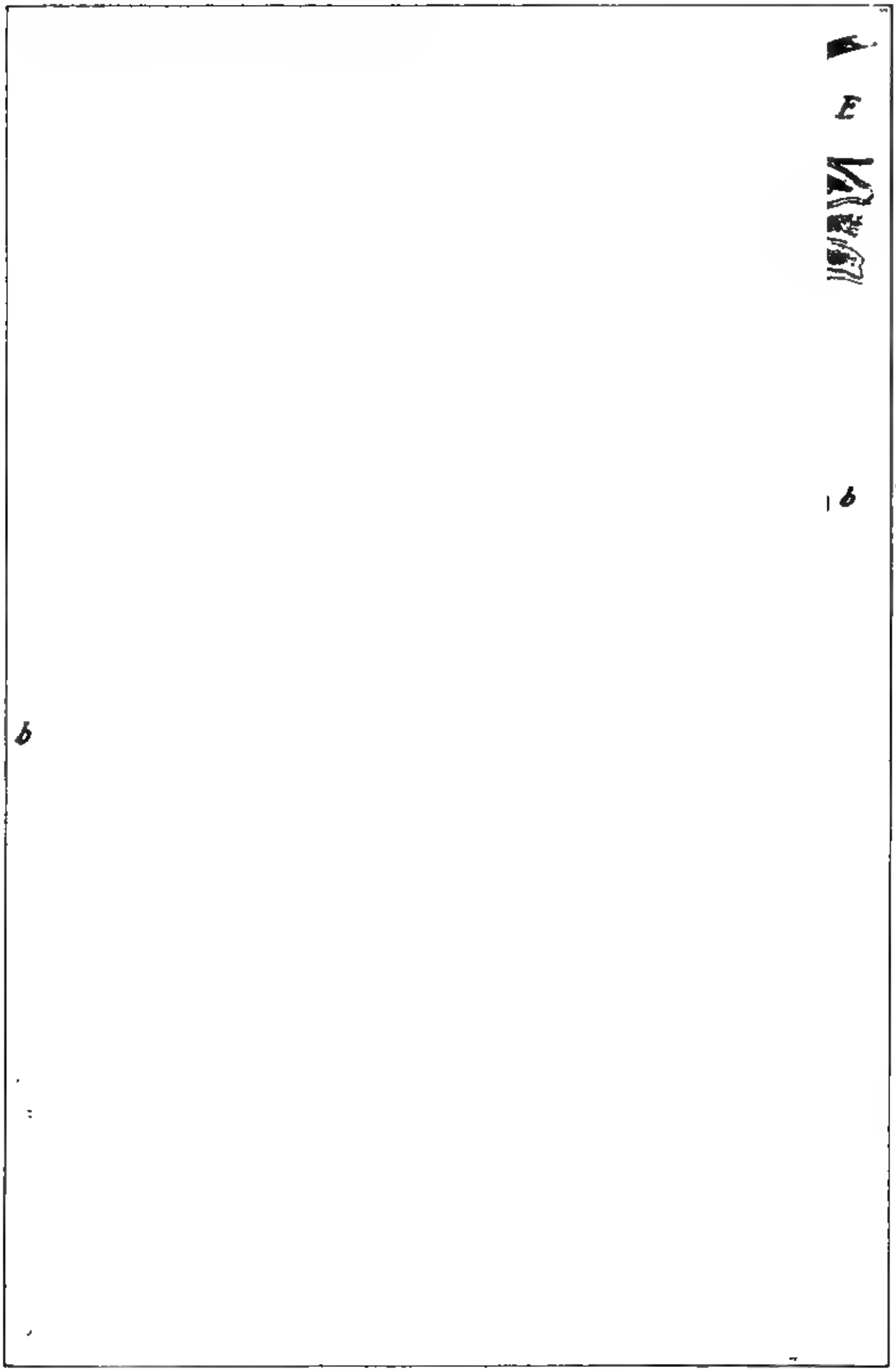

Fig. 162. Difference between an oat leaf dried by the fumes of chlorin or hydrochloric acid and one which has died a natural death.

Fig. 162, *3* illustrates the cross-section through a normally dried oat leaf from a locality free from smoke. In the cross-section the leaf appears as thin as a cord because the mesophyll (V) is approximately *empty* and the cell walls have collapsed. The leaf does not shrivel in the same way around the larger vascular bundles because the strong layers of bast serve as stiffening; they look like knots in the cord-like form. In spite of the great drying

Fig. 163. Leaves of a red beech, affected by sulfurous acid. (After v. Schröder and Reuss.)

of the leaf, the epidermis retains its natural height and at most turns *a pale quince yellow* like the bast cords, and is thus distinguished from that injured by acids. Fig. 162, *4* is a magnified group from Fig. 162, *3*. *E* indicates the epidermis; below this, the collapsed mesophyll cells in which the scanty cytoplasmatous remnants of the cell content have been made recognizable by soaking the section in water. Also in the oat leaf which has matured slowly in continued wet weather the part injured by acid differs in color

from the normal since it has assumed a lemon yellow color in the walls of the bast layers and epidermal cells. The intensity of the discoloration is connected with the quality of tannin. In observing differences in color one must work quickly, since the coloring matter is soluble in water.

All that has been said here of grain varieties may not be applied without limitation to other plants. As a general occurrence may be considered only the fact that in all ***kinds of sudden death,*** the cell contents are abundantly

Fig. 164. Birch leaves injured by sulfurous acid. (After v. Schröder and Reuss.)

Fig. 165. Rose leaf and Fig. 166. Beech leaves injured by hydrochloric acid or chlorin fumes. (After v. Schröder and Reuss.)

retained, while they are for the most part used up in respiration when the leaf has lived out its life naturally.

In order to emphasize the habitual differences in the manner of attack of the vapors of sulfurous and hydrochloric acids we will give here illustrations of injured leaves copied from the repeatedly cited works of v. Schröder and Reuss.

In Fig. 163 we see a leaf of a red beech taken from the vicinity of a silver smelter, which had been injured by SO_2. Fig. 164 shows a birch leaf

from the neighborhood of a copper mill likewise injured by SO_2. The common characteristic consists of more or less sharply defined brown specks in the intercostal fields. The spots are usually surrounded by a brown zone which may vary in tone. In many trees (for example, the red beech) a transparent yellowish green band of diseased but not dead tissue is found around this peripheral zone.

Figures 165, 166 and 167 illustrate leaves from a rose plant, a beech and a birch, which have been artificially injured by hydrochloric acid. They have the dry periphery, which may usually be observed after the action of pure chlorin vapor. Nevertheless, it should be emphasized that in testing smoke effect no definite conclusion may be drawn from such structural pictures showing the habit of growth, because, on the one hand, the forms of injury vary according to the individual habitat and development of the tree and, on the other, different factors may produce similar injuries.

Hydrofluoric Acid.

More often than was formerly supposed, hydrofluoric acid produced by the operation of superphosphate, glass and chemical factories has proved injurious to vegetation. The fact, at first so puzzling, that smoke from kilns and terra cotta factories is very injurious in many cases and in others non-injurious has been explained by this action of the acid. The difference in effect depends upon the presence and amount of fluorin compounds to be found in the clay and raw phosphates. According to Ost, action manifests itself in small, brown, corroded spots which in many plants are surrounded by a yellowish zone. Smoke experiments carried on by other investigators produced in oak leaves narrow, yellowish brown, sharply defined peripheral discolorations. The Norway maple showed similar tracery along the edges of the leaves and the leaf surface and later also turned brown. Lindau[1] describes the anatomical condition in the oak. He found both of the epidermal layers to be intact and the contents of the mesophyll cells slightly browned. The individual chloroplasts were still recognizable, "but the rest of the cell contents had an oily appearance."

Fig. 167. Birch leaves injured by hydrochloric acid or chlorin fumes. (After v. Schröder and Reuss.)

[1] Loc. cit., p. 250.

In regard to the forest trees, which come most under consideration, we find it stated that the spruce, even one day after artificial smoking, shows some shoots with a whitish gray discoloration; in fact, they had wilted. After a second smoking the little trees were set out of doors, where the color tone, which originally had been a whitish, yellowish gray, passed through all the gradations from yellow and yellowish red to the "characteristic red of injury from acids."

Pines, larches, and acacias, like the spruce, were found to be discolored in the vicinity of a phosphate factory where hydrofluoric vapors were developed in the removal of phosphorite containing the calcium-fluorin by the use of sulfuric acid[1]. Mayrhofer[2] was able to prove a strikingly high content of fluorin in the needles and leaves at a distance of 500 to 600 m. from the factory. The effect of such an exhalation may be absolutely destructive to grain. Thus Rhode[3] observed that in some plots rye developed no kernels at all, or only deformed ones.

My own investigations were made only on preserved material of dead spruce needles which I had received from Professor Ramann, but, what is most important, the condition found in them agreed with the effects obtained with sulfurous acid. Only, in the needles affected by the hydrofluoric acid, I found, however, a wrinkling of the tissues as a result of the shrivelling of the cell walls. It must be concluded from this that the drying of the needles. which appears so quickly with the use of sulfurous acid, takes place only after the direct action of the acid has already produced a change in the form of the tissues. The contents, however, had not dried against the walls as in the action of sulfurous acid, and, on this account, could not have contributed to the stiffening of the walls themselves.

Nitric Acid.

We find only one note by König[4] on the influences of *nitric acid* (or nitrogen tetroxid). With 5 grains nitric acid (reckoned on nitrogen tetroxid) to 100,000 l. of air or 0.05 g. of nitrogen tetroxid in one cubic metre of air, he found characteristics occurring in trees which resembled those appearing after the action of sulfurous acid and hydrochloric acid. The air generally contains only 0.00003 g. of nitric acid in one cubic metre.

Ammonia.

Ammonia and ammonium carbonate in quantities far beyond that of the usual content of the air, which at most may be assumed to be 0.056 mg. per cubic metre, were found to favor growth. In general manufacturing processes, however (ammonium sodium processes, etc.), such large amounts

[1] Allgem. Forst. u Jagdzeitung 1891, p. 220.
[2] Mayrhofer, J. Über Pflanzenbeschädigung, veranlasst durch den Betrieb einer Superphosphatfabrik. Freie Vereinigung d. Bayr. Vertreter für angewandte Chemie. Vol. X, p. 127.
[3] Rhode, A. Schädigung von Roggenfeldern durch die einer Superphosphatfabrik entströmenden Gase. Zeitschr. f. Pflanzenkrankh. 1895, p. 135.
[4] König, Denkschrift 1896, p. 202.

become free that they produce injuries, although the plants in general are found to be very resistent. The sensitiveness of different species varies greatly, but the kind of injury shows a great uniformity; namely, a *black coloration* occurring in spots or surfaces.

Experiments made by Börner, Haselhoff and König[1] exhibited in the oak the appearance of dark spots or a complete blackening of the leaves. In the cherry at first a brown color was seen and later black. After a short exposure to the action of ammonia the leaves and blades of barley were bleached white on the side turned toward the sun. Rye and wheat showed rusty spots and edges.

In addition to the cases already known in literature, I will add here a few of my own observations. I found the leaf tips of barley turning white. The intercostal fields of young chestnut leaves were dark at first, but became black the next day and later dried up. The foliage of some of the red blossoming varieties of *Azalea indica* behaved similarly, while in a variety standing nearby but bearing white blossoms only a browning of the leaf tips and edges appeared. Along the edges of the outermost tips of blossoms of the red variety, white, nearly round, or wedge-shaped spots resembling a natural variegation were found, while blossoms of the white variety within the same length of time remain unchanged with the exception of scattered small, brown spots. No after effects could be perceived after the plants had been removed from the ammonia atmosphere; but there was some reaction in the inflorescence of a cineraria. The red, outer blossoms which had turned blue from the ammonia, became red again some time after their removal from the ammoniacal atmosphere.

The spruce furnishes an example of the influence of the developmental stage on the amount of injury. The old needles took on a pitch black color and were retained, while the color tone of the young, delicate needles, at first a dirty green, later passed over into a faded, reddish yellow. The individual power of resistance in the different needles is shown especially clearly in an experiment in which some needles could be observed on branches, among the pitch black ones, which showed no discoloration or at most only a darker green. The black color was due mainly to the pitch black color tone which the protoplasma of the epidermis and mesophyll cells had assumed. The cell walls were only slightly brown. In the cells most injured the contents had become a consistent, granular, doughy mass, which at times had drawn back from the walls. The contents of the guard cells of the stomata were also pitchy black, never red, as in injuries due to acids. In the transitional places between tissue which had remained healthy and that which had blackened, it was noticed that the protoplasmic mass in which the chloroplasts were imbedded had already turned black, while these granules ap-

[1] Zeitschr. f. Pflanzenkrankh. 1893, p. 100. Lindau (loc. cit., p. 286) describes the action of the strongly concentrated ammonia gas on the plant cell; in the interior of the leaf the cells usually show very strong plasmolysis; the contents become indistinct and at times drops of oil are exuded. In this a brown to black coloring matter is given out which tinges the entire contracted contents. This proves later to be a ferment.

peared unchanged in form and position. Only later the green coloring matter in the protoplasm was found to have changed and become a dirty brownish green. Then the ground substances of the chloroplasts united with the other cell contents apparently leaving behind some granular remnants.

The ammonia might also exercise some special poisonous effect on the cell contents besides combining with the acids as has been assumed in another place. Kny[1] has already called attention to the fact that, according to the statements quoted in the literature on this subject, the protoplasm in very different parts of the plant possesses an alkaline reaction without having influenced the chloroplasts. The same author has shown that a very dilute ammonia solution injures the assimilatory activity.

In one case, where the wall of a stable was used as the back wall of a greenhouse, the way in which ammoniacal poisoning may often take place was clearly demonstrated. When the heat was turned on in the autumn, ammonium carbonate developed from the wall, which, in a short time, blackened the leaves of Aucuba, *Viburnum Tinus, Prunus Laurocerasus,* the Dracaenae and other plants in the greenhouse. Only the tissue immediately adjoining the veins of the leaves remained green.

Tar and Asphalt Fumes.

The discoveries concerning the injuries of tar and asphalt fumes have been explained only recently, since the material for observation has become more abundant. Aside from the effect which the asphalting of streets can produce at times in sensitive plants, the factories preparing the carbons for arc lights are to be considered as essential causes of disease.

Roses rich in tannic acid, strawberry leaves, *Ampelopsis quinquefolia* and chestnuts should be named as the most important plants showing injury from asphalt fumes[2]. Different varieties of roses suffer in very different degrees; for example, Tea and Bengal Roses are less affected; Remontants and their hybrids, however, are for the most part very severely attacked. Parts of the outer membrane, or the whole leaf surfaces become a dull black. Usually if the whole surface is not discolored (Fig. 168 *1a*) the blackened places occur as interrupted or connected bands between the larger lateral ribs, that is, in the intercostal fields. If the sepals have been affected by the fumes, the blossom buds unfold only poorly. Soon after the appearance of the blackening, the contents of the epidermal cells of the upper side will be found deeply browned, granular and lumpy, and usually deposited along one of the horizontal walls. The cuticle is not browned and apparently unchanged. When the leaf is more diseased, the epidermis of the under side becomes affected in the same way and later collapses. On the other hand, the mesophyll is but little irritated. The fumes act only on the exposed surfaces of the organs; all the covered parts (Fig. 168 *1b*) remain un-

[1] Bot. Centralbl. 1898, Vol. LXXIII, p. 430.
[2] Sorauer, P. Die Beschädigungen der Vegetation durch Asphaltdämpfe Zeitschr. f. Pflanzenkrankh. 1897, p. 10.

Fig. 168. Virginia creeper, strawberry and rose leaves injured by tar fumes.

changed. If the middle part of the leaf is injured, the edges curl up like the sides of a boat.

Attention should be called in passing to the fact that in many roses (for example, *Rosa turbinata*), a similar discoloration appears in the late autumn. In this rose, for example, I found that the older leaves, still hanging on the stems, had become dully spotted with black without any previous red coloration; this arose from the contraction and browning of the contents of the epidermal cells. These cells, however, retained their natural turgidity and height, but began to collapse after having been affected by asphalt fumes. In this the contents of the mesophyll also retain their normal consistency and position for some time, while, in the autumn coloration, they contract at once and change into uniform masses, at first green, but later turning brown. Under the microscope parasitic blackening (*Asteroma radiosum*, etc.) can be distinguished easily from asphalt corrosion.

Before I began my experiments, Alten and Jännicke[1] had already described the blackening of roses and strawberries caused by the action of asphalt fumes. They considered the iron which was proved present in these fumes to be the actual injurious factor since it combined with the tannic acid of the cells and they supported this theory by experiments in which they produced black spots, corresponding to those in asphalt injuries, by sprinkling the leaves with ferrous chlorid and ferric sulphate. Ferric chlorid did not have this effect.

I could not obtain this result and observers who have sprayed with iron solution as a means of overcoming chlorosis and icterus do not report any blackening.

In the strawberry leaf illustrated in Fig. 168, *2* (a cultivated form of *Fragaria chilensis*), only a partial blackening of the upper side is found at *g* because only this part of the leaf had lain free; otherwise the phenomena were similar to those in roses, the curling of the leaf edges, the partial drying of the leaf serrations, etc.

In Fig. 168 *3* we see a leaf of *Ampelopsis quinquefolia* a few weeks after it had been acted upon by tar fumes from a factory making electric light carbons. The less diseased leaves were found to be still green but not outspread; the edges were curled up like bowls and the inside of the blade wrinkled by the outpushing of some of the tissue lying between the finer ramifications of the veins. At times small places with a cork colored upper surface were found near the midrib. With more extensive injury, these places were always present and passed over partially into blight spots which became dry and ultimately united. Finally, each leaf may show very regular markings due to the drying of the intercostal fields. (Fig. 168 *3s*.) These dry places often break away, due to the rubbing of the leaves against one another, thus producing a lattice-like perforation (Fig. 168 *3l*).

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[1] Alten, H., und Jännicke, W. Eine Schädigung von Rosenblättern durch Asphaltdämpfe. Ref. Zeitschr. f. Pflanzenkrankh. 1891, p. 156 und 1892, p. 33.

Young branches become corky on the side affected and show fine cracks. Any existing air roots dry up.

When the action of the asphalt fumes ceases, the leaf's attempt to heal itself at once become apparent. In case the palisade parenchyma has been only a little, if any, affected, it may elongate somewhat and slightly push out the *epidermis*, which has *collapsed to a state of irrecognizability*. If, however, the palisade layer has also died the healthy underlying mesophyll develops a perfectly regular layer of flat cork cells. The same process may be noticed on the leaf stems: the brown, dead, ruptured, outer cork and parenchyma layers, together with the hard bast bundles which at times have also succumbed to the necrosis, are separated from the healthy tissue by a broad cork band which in extreme cases extends as far as the cambium.

Vitis vinifera suffers sooner and more than does Ampelopsis, so that its leaves, at times, are curled entirely out of shape and perforated. In this it was observed that in places lightly affected the guard cells of the stomata had suffered first. Other plants behaved differently; in regard to these, reference must be made to my original work on the subject. The corrosion of the epidermal cells, however, may be cited as the universal characteristic.

As in all injuries due to gaseous bodies, the fact that the injury is chronic, or acute, determines the results; in the former case, with slower action, the organ affected can remain alive for some time by its counter action and may slowly live out its life. In this the characteristics differ from those found when the action is that of more highly concentrated gas waves, which result in a rapid death. Thus, for example, in the slow death of spruce needles, a strong, red discoloration of the cytoplasm of the guard cells and later, in fact, of their walls was perceived in the still green parts, but not if the injury was acute. The walls of the vascular *bundles element* also discolored; as always happens from asphalt fumes, the cell walls suffer especially quickly. This is seen very well in the older fir needles which acquire a metallic lustre.

Bromine.

In the ordinary industries in which bromine is produced injuries due to bromine alone may scarcely be spoken of because, as a rule, sulfurous acid works with it. At considerable distances from the factories the bromine may still be perceived by its odor, but no decided injuries from the acid. Therefore, any description of natural occurrences in the neighborhood of bromine factories may be omitted here and only the behavior of plants under the artificial action of intense bromine fumes be described. I carried out experiments as follows for 4 days:—

Small, well-rooted spruce saplings in pots were exposed several hours each day to gaseous bromine, being left out of doors between times. The branches nearest the bromine sources naturally suffered most and all their needles turned brown. On the less injured branches many needles were found to be partially brown from the tip back, while on the branches furthest away from the course of the bromine only a few brown needles were found

among the healthy ones. The red brown, which in the beginning was very bright, soon turned into a gray brown. The needles kept this color until they fell, about two weeks later, but this took place only on greatly injured branches. It was found in the discolored places of the slightly injured needles, remaining on the branches, that the walls of some groups of mesophyll cells near the epidermis had turned a faded to reddish yellow, while the contents had lost their color and finally with a complete disorganization of the walls had dried up. In this they not infrequently passed through a stage of foamy consistency. For some time after the action of the gas the guard cells of the stomata seemed to have become discolored up to the healthy tissues only in the zones of transition whereby their walls had turned a brownish yellow. The epidermis was slightly browned; the sub-epidermal prosenchymatous fibres were found to be colorless. The mesophyll near the brown places remained green and had either a flocculent green content or the chloroplasts were united into lumps. Healthy tissue adjoined this immediately.

At places more strongly injured the vascular bundles were also affected and discolored just as from sulfurous acid, but the color tone of the injured needles was only rarely a reddish brown. They were generally a yellowish brown and less hard, a fact distinguishing them from needles affected by SO_2. The slight amount of difference is of less moment here because, as said above, in general injuries from bromine occur as a rule in connection with those caused by sulfurous acid.

CHAPTER XVII.

SOLID SUBSTANCES GIVEN OFF BY CHIMNEYS AND THE DISTILLATES THEY CONTAIN.

The best survey of the material from the streams of smoke affecting vegetation is found in a table by Wislicenus[1] which we may repeat here unchanged because it is so very clear.

No general decision can be reached as to the substances given in this table. *Under certain circumstances* they may become injurious and, indeed, very injurious but, in other cases, they do not cause any loss of crops worth mentioning. This depends not only upon the greater or less exposure of the plants but also on locally different, secondary conditions. Aside from the individual sensitiveness of different species of plants, the constitution of the soil and the weather at times become decisive, especially with fine flying ashes.

It should be mentioned in connection with the injuriousness of *tar vapor* that tar vapors from *lime kilns* also cause injuries. In burning limestone, when the calcination begins, that is, the breaking down of the carbondioxid, the smoke becomes laden with great quantities of the distillates given in the table, which produce corrosions similar to those described under asphalt fumes. These vary with the plant.

The *injuriousness of soot* was previously universally overestimated and is still, to some extent. The more recent investigations of v. Schmitz-Dumont and Wislicenus[1] confirm Stockhardt's older discoveries, that soot is usually non-injurious. More delicate plants may show corrosion because of phenol, etc., carried in the soot.

The theory of the stoppage of the stomata must be left undiscussed. According to my investigations of plants covered with soot the cases are very rare in which the soot particles have succeeded in getting into the cavities of the stomata, or actually have stopped them up, and even in these rare cases, I have not been able to perceive any change in the surrounding cells. Considerable quantities of extractive substances (sulfates and phenols) must first be leached out from the soot before any injury may be

[1] Wislicenus, H. Zur Beurteilung und Abwehr von Rauchschäden, Vortrag in Dresden am 31 Mai 1901. Zeitschr. f. angewandte Chemie 1901, Part 28, Taf. V.

CHEMICAL CONSTITUTION OF

THE FIGURES INDICATE

1	2	3	4	5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

VARIOUS KINDS OF SMOKE

VOLUME PERCENTAGE)

6	7	8	9	10	11	12	13	14	15	16	17	18
Gases from Pyrites Ovens	Waste Gases from Acid Factories (Halsbricke)	Waste Gases from Glass Factories, Using the Sulfate Process	Waste Gases from Hollow Glass and Opalescent Glass Factories, Using Cryolith, Fluor-spar	Waste Gases from Superphosphate Works	Waste Gases from Round Tile Factories	Bleaching Factories, Sulfate, HCl, Chlorid of Lime	Keramic Enamels (NaCl process)	Bleacheries (Paper, Wood-pulp, Straw-bleaches)	Blueing Works, Sulfite-cellulose-beet Sugar (Saturation) Alum Factories, Oil Refineries, etc.	Manufacture of HNO_3, Nitrogen Compounds and Explosives	Locomotive Smoke	Volcanic Exhalations
81					68.44						49.39	
10					8.96						6.3	
	2.5				7.77						5.41	
					(—)						(—)	
				Much!	15.7						40.86	
8.5 Used: 0.45	0.26	In Annealing 0.089 In Fusing 0.443			— 0.074				Ultra-marine Ovens 3.0..0.5		— 0.039	
					0.023						0.004	
			!	Chiefly Waste Gases Containing Fluorin	!!							Boric Acid
				HNO_3								

Illuminating Gas, Soda Residue in Refuse Heaps.)

Illuminating Gas, Prussic Acid, Ferrocyanid, etc.)

Photographic Papers, etc.)

manifested. This is shown in Wislicenus' experiments with the soot from hard coal, lignite and benzine, as well as extracts from soot, by means of which the leaves of the hornbean and linden and later also spruce needles were slightly etched. Probably, as they dry up, the salts effect an osmotic removal of water and a drying of the cells. The same experiments also dispelled the fear that a thick coating of soot absorbs the light, changing it into heat and, therefore, acting disadvantageously.

It is theoretically possible that the *carbon dioxid* carried in the smoke can act injuriously for even experiments with an extreme increase of this gas above the normal 0.04 to 0.06 per cent. have proved the retardation of assimilation but this can scarcely be spoken of in practical industry. The same holds good for carbonic oxid.

The metallic elements of the smoke from smelters (see table) also enter into the question of the effect of flying ashes. According to Freytag's investigations[1], pure metallic oxids are usually non-injurious. Naturally, foliage bearing such oxids cannot be used as food for animals, since they may easily cause inflammatory diseases.

Also, these metallic elements such as insoluble oxids or carbonates and silicates scarcely injure the aërial parts of the plants more than does the street dust. Soluble compounds, on the other hand, such as arsenous acids, sulfates, and chlorides (*copper, zinc, and lead*) are principally concerned here and produce brown spots through the corrosion of the tissue, as soon as they are deposited on moist leaves. They are said not to injure dry foliage and a subsequent wetting from rain easily washes away the coating. Mercury fumes in the air always act very injuriously. The compounds washed into the soil by rain are absorbed by it and are usually non-injurious. A large accumulation of arsenic (more than 0.1 per cent.) is disadvantageous. Experiments made by Phillips[2] prove that healthy plants undergo no disturbances in growth from the taking up of lead and zinc, while copper acts as poisonously as arsenic and disturbs the root development. Klein[3] and numerous, more recent observers furnish proof of the presence of arsenous acids in plants. Such poisoning of the soil may occur, for example, near copper smelters and in the litigation against the Mannsfeld-Hettstädter copper smelters Grouven refers especially to this point[4]. My own experience in the same region shows that, at present, large surfaces of the fields have become poisoned and, despite very abundant fertilization, yield very meager harvests. The experiments in which soil which had become unfertile was carried from the vicinity of copper works to a region free from smoke prove that the gases in the smoke are not alone the injurious factors,

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1 Freytag, in Jahrb. für das Berg- und Hüttenwesen im Königreich Sachsen 1878, pp. 24 and 86, cit. in Hasenclever.—Landwirtsch. Jahrb. 1882, p. 315-375. In regard to the action of smoke, the author differs from Schröder inasmuch as he does not consider the sulfurous acid as such to be the injurious agent, but only the sulfuric acid which is being formed from it.

2 Phillips. The absorption of Metallic Oxides by plants; cit. Bot. Centralbl. 1883, Vol. XIII, No. 11, p. 364.

3 Chemischer Ackersmann, 1875, Part 4.

4 Fühling's neue landwirtsch. Z. 1871, Part 7, p. 534.

but also the soil which has been rich in copper salts. Even in the latter place, which is free from smoke, the plants (*Phaseolus vulgaris*) became diseased while those sown in the same region in soil which had always been there remained healthy and developed vigorously.

An analysis of potatoes, of which the plants themselves were covered by the metallic dust from a nickel factory, shows how much of the metal may be taken up by the plants during one period of growth. The healthy foliage contained (in percentages of substances free from water and from sand):

Copper oxid	0.198
Zinc oxid	0.169
Nickel oxid	——

The diseased foliage contained (in percentages of substances free from water and sand):

Copper oxid	0.0713
Zinc oxid	0.1712
Nickel oxid	0.0251

Analyses of the tubers from these plants, however, did not give any zinc and nickel oxid, and only 0.0043 per cent. of copper oxid as contrasted with healthy tubers which contained 0.0041 per cent[1].

Besides copper as a poison the arsenic compounds are important because of their injuriousness. According to v. Schröder these impair vegetation even if present in the soil in amounts of less than 0.1 per cent.

Nevertheless, the improved technique of manufacture takes care that more and more of the arsenic, as well as the soluble metal salts, is kept back from the smoke in the flying dust flues, so that at present a fresh metallic poisoning of the soil is less to be feared.

And yet the *throwing off of flying ashes* requires increased attention. A number of my own experiments have shown that with many flying ashes which become mixed with the soil a visible increase of growth may be obtained, while those from other industries have caused poisoning. This is less often a direct injury to the aërial parts of the plants, but more frequently an indirect one, manifesting itself by its effects on certain heavy kinds of soil, rich in water. In aërial injuries, *sodium sulfid* and *calcium sulfid* can produce corrosion in some, more tender plants. The course of the action in the indirect injuries has not yet been sufficiently explained. In my opinion, reduction phenomena in the soil are partially concerned in it by which *hydrogen sulfid* is developed.

In heavy soils deeply covered by flying ashes, especially if they have been heavily fertilized with lime, a phenomenon of disease appears to such an extent in barley (I have called it "spotted necrosis") that the harvest is greatly reduced. All parts of the plants, even the beards of the glumes, appear closely stippled with brown. The brown points represent centers of

[1] König, J. Denkschrift der Landwirtschaftl. Versuchsstation Münster i. W. 1896, p. 204.

dead tissue of which parasites certainly are not the cause. Black fungi may later infest these spots and then this complication is described as the "*Hormondendron*" disease. The spotted necrosis is, however, not a disease peculiar to regions of flying ashes but it undoubtedly occurs most intensively there. I found it could be lessened by a heavy application of lime.

The opinions handed down by Steffeck[1] give the best references to the injurious action of hydrogen sulfid. In them the repeated decrease in the value of the harvest by a mechanical coating of the soil is also considered. I also know of cases in which a deposition of ashes on vegetable plants, especially varieties of cabbage, was so heavy and could be removed to such a slight extent that the quality of the plants became poor, or they were absolutely unsalable. If fodder carrots and sugar beets had been heavily covered and their leaf heads used later as fodder some of the animals died. Incredibly large amounts of ashes were found in the stomachs of these animals.

Hydrogen Sulfid.

In consideration of our theory that hydrogen sulfid may be formed in certain heavy kinds of soil after flying ashes have been deposited on them, I made some experiments with barley. In some pots, pieces of potassium (poly sulfids) from sulphur liver were laid between the young barley plants; in other they were put in the water in saucers in which the pots of barley stood. A piece of lead paper, laid between the plants, slowly turned brown. After six days the leaves began to turn yellow usually, in fact, beginning at the center, more rarely at the tip. The discolored areas appeared to be more watery and *transparent* than when the yellow discoloration was produced by other causes[2]. A wilting of the tissue followed the yellow discoloration and a drying of the green leaf surface lying above it, together with the assumption of a grayish yellow color.

The first symptom of the disease is always the bleaching of the chlorophyll coloring matter, which at once begins to spread into the cytoplasm. This is not preceded, nor accompanied, as in other cases of poisoning, by a contraction of the primordial pouch (or a shrivelling of the chloroplasts). Instead of this, in places, the passing over of the cell water into the intercellular spaces becomes noticeable, thereby explaining the transparent appearance of the yellowish areas. The outlines of the individual chloroplasts then disappear up to the appearance of a granular mass which is contracted in the centre of the whole cloudy, pale yellowish, green cyptoplasm. The impression given is that here the cell contents as a whole swell up into an uniform, doughy mass, while in the action of the hydrochlorin and hydrochloric acid shrivelling phenomena are perceived and, with sulfurous acid, a process of drying of the contents which remain differentiated.

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1 Steffeck, Die durch gewerbliche Einwirkungen hervorgerufenen Flurschäden und Verunreinigungen von Wasserläufen und Teichen. Magdeburger Zeitung 1907. Nos. 329 and 331.

2 Sorauer, P. Beitrag zur anatomischen Analyse rauchbeschädigter Pflanzen. Landwirtsch. Jahrb. 1904, p. 643.

In oats the bleaching of the chlorophyll coloring matter was slower and less intensive. As a result of the subsequent diseased condition of the roots, the walls of the vascular bundle elements became a deep brown.

SODA DUST.

Ebermayer[1] has reported on the injuriousness of *sodium fumes*. In the manufacture of cellulose, sodium lye, under high pressure, is permitted to act on pulverized pine wood. To get back the sodium, the lye used is vaporized and the residue burned to destroy the organic substances. In this way a considerable amount of sodium carbonate is freed in the air. The leaves of fruit trees near such factories appear brown or black and die after a short time.

Leaves which had been dipped into a dilute sodium solution (1.01 specific gravity) took on the same color; apple leaves appeared to be somewhat less resistant than pears and plums.

In regard to soda dust, as yet only those cases have been known in which soda from ammonium soda factories was turned to dust by an improper method of ventilating the factory rooms. The soda dissolved by dew, or rain, easily produced in many trees an appearance of the injury from acid vapor, such as the dying of the edges of the leaves, or scattered corroded areas.

In doubtful cases the expert is helped by the condition in wild grasses and especially grain stalks which assume a *lemon yellow color*. Grain can become sterile according to the time and intensity of the giving off of the soda dust and trees may gradually be killed by the repeated annual injury to their leaves. Besides this, different plant species vary greatly in sensitiveness and often are resistant to soda but sensitive to acid smoke, or conversely. My experiments on grain and wild grasses (*Agropyrum repens, Agrostis vulgaris*, Lolium, etc.), in which I covered them with dust while wet with dew, gave the same yellow discoloration, even in the glumes, just as in natural injuries[2] which were demonstrable at a distance of 2 kilometers from the factory. König[3] observed that the edges of barley leaves became white. Red clover is said at first to show small black spots on the leaves, some of which later become entirely black and drop off. The same is true of potatoes. König found perforations near the brown edges of the leaves in oaks as in cherries. The needles of the white fir are said to become yellow at the tip and fall off. As a result of his analyses, König considers the action of the soda to lie not only in a humification of the leaf substances, but also in the taking up of soda by the leaves, from which it wanders down to the roots. An increase in acids, especially silicic and sulfuric acids, takes place at the same time with the increase of the amounts

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1 Ein Beitrag zur Pathologie der Obstbäume. Tagebl. d. Naturf.—Vers. zu Hamburg, cit. Biedermann's Centralbl. 1877, II, p. 318.
2 Zeitsch. f. Pflanzenkrankh. 1892, p. 154, note.
3 Börner, Haselhoff and König. Über die Schädlichkeit von Sodastaub und Ammoniakgas auf die Vegetation. Mitgeteilt von König, Landwirtsch. Jahrb. XXI, cit. Zeitsch. f. Pflanzenkrankh. 1893, p. 98.

of sodium[1]. Often the phosphoric acid and chlorin also increase. In the injuries due to acid gases this reaction of the plant body is shown also further by the fact that the leaves, not yet injured beyond a certain extent, contain more bases than do healthy ones.

Control Plants.

Reference must be made to technical handbooks for technical regulations regarding the avoidance or decrease of injuries due to smoke and flying ashes. However, I would like to give here one method in clearing up the question whether the injuries already perceived are connected with the poisoning of the soil, or are due to the purely aërial action of gas waves containing acid. This method is that of control plant cultivation and is carried out as follows: Wooden cases, containing at least one cubic meter, are sunk in the fields in question and are filled with soil which, before witnesses, has been taken from a region free from smoke. On the other hand, soil taken from the fields in question is put in similar cases which are sunk in a field in a region free from smoke. Both series of cases are then sown in the same way with beans (*Phaseolus vulgaris nanus*) and harvested simultaneously after a number of weeks. The harvest is examined microscopically and chemically.

The poisoning of the soil is proved by the fact that the plants grown in the soil taken from the fields in question but kept in cases in regions free from smoke become diseased with the same characteristics as those near the source of smoke. If, on the other hand, the beans from the cases filled with soil from a region free from smoke which had been sunk in the fields in question, near the injurious industrial establishment, show the characteristics of smoke poisoning, this then proves that the dangerous streams of smoke alone are sufficient to injure vegetation.

These comparative cultures have the advantage of giving the contesting parties an insight into the kind of injury which is recognizable to the layman and thereby furnish the means of an unification of opinion, thus avoiding lengthy lawsuits. It is well in regard to these to strive for the formation of federal *smoke commissions*. We mean by this the appointed persons from among botanists, chemists, agriculturalists and foresters, who would meet together as a commission of specialists and would always be the same for the different districts. By retaining the same persons they would have a more exact insight into the special conditions of their districts and a more assured judgment in these difficult questions.

Illuminating Gas and Acetylene.

The injurious effect which illuminating gas exerts on plants has been ascribed to the hydrogen sulfid abundantly present in it. This is, however, not the only cause, for Kny[2] has shown that gas, carefully purified

1 König (Denkschrift 1896, p. 207), found only in rye, despite a higher sodium content, a smaller ash, and especially less silicic acid. It seemed to him that the silicic acid was dissolved by the soda in the glume and then washed away.

2 Sitzungsber. d. Ges. naturforsch. Freunde zu Berlin in Bot. Zeit. 1871, p. 869.

from hydrogen, is still injurious to roots. I conclude from the violet gray color in many roots of trees injured by illuminating gas that some of the tars, or the ammonia, carried over in the gas are the injurious factors. For the present, this violet discoloration of the roots may be considered the best indication of the injury even if it is not an absolutely certain one. We must agree with Wehmer[1] that such root discolorations occur also in death due to other causes and that often in trees killed by illuminating gas in the soil this characteristic is found only sparingly. The later case is easily explained since only those roots discolor which come in direct contact with the injurious agent and thus cause the death of the tree. The root dying subsequently remains uncolored.

The different trees and shrubs show a great diversity in their power of resistance to the affect of gases. While in Kny's experiments, for example, the elm died very soon, *Cornus sanguinea* withstood the poisoning of illuminating gas without any perceptible injury. An analysis made by Girardin[2] shows how far the effect of a gas pipe may extend. According to it, the soil at the distance of one meter showed empyreumatic oils and sulfur and ammonium compounds.

A further example of the different behavior of plants toward illuminating gas is given by Lackner[3]. His observations, however, relate to the effect which the gas is said to exert when burned in the room. Retention in a room where much gas is burned is very injurious to camilleas and azaleas and ivy is said to die at once. On the other hand, palms, Dracaenae, *Aucuba japonica* and other plants are found to be not at all sensitive to it.

Richter's experiments[4] prove that illuminating gas acts arrestingly on the growth in length of bean seedlings and other plants and favors the growth in thickness. It is not true that the amount of carbon dioxid, rapidly increasing by combustion, acts as injuriously on the plant body as on the animal body, as people were inclined to assume[5]; it is rather to be supposed that different products of incomplete combustion of the illuminating substances should be to blame for this.

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[1] Wehmer, C. Über einen Fall intensiver Schädigung einer Allee durch ausströmendes Leuchtgas. Zeitschr. f. Pflanzenkrankh. 1900, p. 267.

[2] Jahresber. über Agrikulturchemie Jahrg. VII, 1866, p. 199.

[3] Monatsschrift d. Ver. z. Beförd. d. Gartenbaues in d. Kgl. Preuss. Staaten. January, 1873, p. 22.

[4] Richter, O. Pflanzenwachstum und Laboratoriumsluft. Ber. d. D. Bot. Ges, 1903, Part. 3.

[5] We repeat that with otherwise favorable conditions for growth, the presence of carbon dioxid up to a high percentage is useful, since it advances the production of plant substance as shown by the increased elimination of oxygen. According to the investigations of Godlewski ("Abhängigkeit der Sauerstoffausscheidung der Blätter von dem Kohlensäuregehalt der Luft" in Sachs' Arbeiten des bot. Inst. of Würzburg, 1873, III, p. 343-70) the optimum for the carbon dioxid content lies tremendously high (5 to 10%) in comparison with the content of the air. In this way is explained the favorable action of hot beds and of the low sunken glass houses of the gardener warmed with horse manure. Here the high carbon dioxid production of the organic substances, which are being decomposed, is united with the abundant development of heat, weakened light and moist air; i. e. the factors essential for a luxuriant leaf growth. But blossom development is promoted, however, since with the increased carbon dioxid content of the air, the blossoms are formed earlier and more abundantly. (Demoussy, Über die Vegetation in kohlensäurereichen Atmosphären. Compt. rend. 1904, Vol. 139, p. 883).

According to my experience with house plants, the dryness of the air is primarily the chief cause of death, and manifests itself in the drying of the leaf tips and edges.

In regard to the effect of illuminating gas on roots, Böhm's experiments[1], with willow cuttings in bottles of water through which illuminating gas was passed, showed that the action was slowly fatal. The cuttings which died after 3 months had formed new short roots at the expense of the stored starch. The action was thus less intensive than it was when carbon dioxid was passed through the water. In this case all formation of new structures by the submerged stem was suppressed while the upper part, which formed tyloses in its ducts, developed sickly shoots. Death occurred after 2 months. In other experiments in which hydrogen was passed through the water, development was practically normal. (Compare the section on Excess of Carbon Dioxid.)

The plants also died when illuminating gas was introduced into the earth in their pots. Seeds, set in earth through which illuminating gas had passed for almost 2½ years, developed more poorly. If a stream of atmospheric air was drawn through such soils for a considerable time, the soil did not lose its injurious effect entirely so that, as already stated, this effect may indeed be ascribed chiefly to the tarry products which are deposited in the soil in a fluid or solid form.

Späth and Meyer[2] found that even a comparatively small amount of gas (25 cu. ft. distributed daily on 14.19 sq. m. at a depth of 1.25 m.) killed the roots which came in contact with it. Even a greater quantity of gas was found to be less injurious if it reached the trees *during their winter dormant period*. Here too different varieties of trees display a different power of resistance.

Most expedient at present seems to be Juergens' method, as recommended by Böhm, of laying the gas pipes through the streets, etc., in glazed terra cotta pipes which have openings leading to the light standards so that constant ventilation can take place within the terra cotta pipes.

Brizi[3] has made experiments in regard to *Acetylene poisoning*. He found in one Italian city that *Quercus Ilex* died when growing alongside a pipe carrying this gas. Herbaceous plants died in pots and dried up if acetylene was introduced into the soil. The nuclei disappeared in the palisade cells of Coleus, the roots lost their hairs, the lateral roots seemed wilted, crushed and brown, the bark cells lacked all fluids. In *Evonymous Japonica* the plants in dry soil seemed perfectly normal after 7 days, while, in moist earth they had all dropped their leaves after the 6th day and most of the young roots had died. The laurel and the grapevine behaved similarly.

1 Über den Einfluss des Leuchtgases auf die Vegetation. Sitzungsber d. k. Akad. d. Wissench. zu Wein, Vol. LXVIII B.

2 Späth and Meyer, Beobachtungen über den Einfluss des Leuchtgases auf die Vegetation von Bäumen. Landwirtsch. Versuchsstat. 1873, p. 336.

3 Brizi, U. Sulle alterazioni prodotte alle piante coltivate dalle principali emanazioni gasose degli stabilimente industriali. Staz. sperim. agrar. ital. XXXVI; cit. Zeitschr. f. Pflanzenkrankh. 1904, p. 160.

Brizi considers the action of the gases contained in the acetylene and the admixtures to be a displacement of the normal air, containing oxygen, so that the roots suffocated and he thinks that illuminating gas will act similarly but more powerfully. The moisture in the soil, therefore, favors the injury because it reduces the imperviousness of the soil to the gas. This theory of Brizi's of the suffocating effect on the roots exercised by illuminating gas, together with the products its contains, finds support in so far that I have perceived clearly the odor of butyric acid when cutting the roots of lindens in Berlin after poisoning from gas and I could determine a violet brown discoloration of the membrane of roots of trees which had died because of stagnant water.

CHAPTER XVIII.

WASTE WATER.

Water Containing Sodium Chlorid.

Of all the injuries caused by waste water, the most common are those produced by sodium chlorid. These are found especially in regions where extensive hard coal mining takes place. From the experiments published by König[1] in association with Storp[2], Böhmer,[3] Stood[4] and Haselhoff[5], we will quote a few figures about the composition of mine water which will suffice to show what quantities of sodium chlorid and other salts are contained in it at times. It contains per litre

Name of Mining Company	Sodium chlorid	Calcium chlorid	Magnesium chlorid	Potassium sulfate	Magnesium sulfate
Levin	65.949 g	11.056 g	3.736 g	0.659 g	—
Matthias Stinnes..	33.244 g	3.631 g	1.735 g	—	0.042 g
Saline Königsborn.	45.413 g	4.061 g	0.189 g	—	1.256 g

From these examples it is easy to reckon the effect of irrigating, or flooding land with such solutions. The action will be direct, as well as indirect, according to the changes which the soil undergoes. In the latter connection, the fact that nutrient substances in the soil (Potassium, calcium, magnesium, and, under certain circumstances, also phosphoric acid) are dissolved in increased amounts and washed away should receive first consideration. This leaching process begins with the percentage of 0.5 g. sodium chlorid per litre. Nevertheless, all water containing any considerable amount is dangerous for irrigation. Pot experiments with meadow grass show a considerable reduction in harvested substances corresponding to the loss in nutrition of the soil.

A second disadvantage of irrigation with water containing sodium chlorid is the *increased density of the soil.* Even 0.41 per cent. sodium

1 Die landwirtsch Versuchsstat. Münster i. W. Denkschrift 1896, p. 153.
2 Landwirtsch. Jahrbücher 1883, XII, p. 795.
3 Ibid, p. 897.
4 Landwirtsch, Versuchsstat. 1899, p. 113.
5 Landwirtsch. Jahrbücher 1893, p. 845.

chlorid in the soil is enough to make it sterile because of the density. Sanna[1] found near salt works a preponderance of fine earth over coarse particles and calls attention to the fact that the work of the soil bacteria is stopped by the decreased supply of air. Such soils must unquestionably be laid open in furrows before winter so that they may again undergo a breaking up by frost. Finally, one more point must be cited to which Preglion[2] has called attention. He studied the peculiar deforming of the ears which is called "Garbin", and ascribed to the action of sea winds. According to him, however, physiological drought is to blame for this. The salty soil holds the water so fast that the roots are not able to take it up in sufficient amounts.

In regard to the direct effect, consideration must be given to the fact that a plant can particularly adjust itself to water containing salt, according to its own peculiarity, and change its habit of growth accordingly. Höstermann[3] has proved that meadow grasses take on a xerophyte structure; they become smaller and squattier; the internodes shorter and the leaves smaller; the plant growth is meagre and the root system develops weakly. Transpiration retrogresses and the energy of assimilation is arrested with 0.05 per cent. In regard to the germinating power of seeds, it has been observed that weak concentrations (0.5 to 0.75 per cent.) act favorably, but above that amount injury sets in.

Areschoug[4] mentions other phenomena of adjustment, since he considers the retention of water in tissues not directly connected with assimilation (storage tracheids, slime cells) to be a protection against the accumulation of chlorids. Also, the hydathodes appear to eliminate water containing sodium chlorid. Diels[5] found that structural adjustment for arresting transpiration increases with the saltiness of the habitat. It might be concluded from this that vegetation from the coast would also behave differently in basins of water containing different amounts of salts. Rostrup[6] also actually calls attention to this point. Pines suffer the most and birches the least. It is evident from the notes made by the Economic Society of the Province of Maribo after the floods of 1858, '63, '65 that the effect of salt water is greater the more loam the soil contains. Of winter plants thus flooded, rye suffered more than wheat. In early spring seeding on land saturated with salt, barley and peas were injured most of all. Mangelwurzels, potatoes, white clover and ray grass did not seem to suffer very much from the effect of salty soil. On the other hand, red clover was very sensitive. In Wohltmann's experi-

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1 Sanna, A., Einfluss des Seesalzes auf die Pflanzen. Staz. sperim. XXXVII; cit. Centralbl. f. Agrikulturchemie 1904, p. 826.

2 Peglion, V, Der Salzgehalt des Bodens und seine Wirkung auf die Vegetation des Getreides. Staz. speriment agrar. ital. 1903; cit. Centralbl. f. Agrikulturchemie 1904, p. 507. Ricôme, Influence du chlorure de Sodium, etc.; cit. Zeitschrift für Pflanzenkrankh. 1904, p. 222.

3 Höstermann, Einfluss des Kochsalzes auf die Vegetation von Wiesengräsern. Landwirtsch. Jahrb. Suppl. 1901; cit. Centralbl. f. Agrikulturchemie 1903, p. 211.

4 Areschoug, F. W. Untersuchungen über den Blattbau der Mangrovepflanzen. Bibl. bot. 1902; cit. Bot. Jahresber. 1902, II, p. 295.

5 Diels, L. Stoffwechsel und Struktur der Halophyten; cit. Bot. Jahresber. 1898, I, p. 606.

6 Rostrup, Plantepatologi, p. 74, 75.

ments[1] with artificial sodium chlorid fertilization, barley and wheat (among summer grains) showed great sensitiveness, while winter wheat throve fairly well even with heavy additions of salt. Peas failed entirely with a strong fertilization; oats were more resistent. Winter rye was found to be the least sensitive. In potatoes, the starch content was much decreased; the protein content not affected; the amount of ash increased. In sugar and fodder beets the quantity harvested was increased without a decrease of the sugar content. Their descent from coast plants may be noticed in this.

The effect of salty soil manifests itself in trees only after they have stored up the salt for some time. Weber[2] is an advocate of the theory that, in many cases, it is not the excess of salt but the marshiness of the soil which causes death. He found in the yellowed branches of *Salix viminalis* in the valley of the Lahn near Bersenbruck, where the mine water flows in from Eversburg, that the leaves had a chlorid content of 1.309 per cent., while those of healthy plants contained only 0.877 per cent. We find abundant statements concerning the behavior of decorative plants in Otto's book[3]. He gives, as a universal characteristic, the reddening of the tips of plants before they die.

Aside from mine water, a high content of sodium chlorid manifests itself in the *sewage fields*. In summer the concentration of the liquid sewage becomes relatively large and many plants are found "to scorch" as the gardener on such fields says. Tobacco has proved to be very sensitive so that up to the present there has been a complete failure of the tobacco crops, as emphasized by Ehrenberg[4], who has considered very thoroughly all the injuries due to liquid sewage.

Besides the sodium chlorid the amount of *magnesium chlorid* also comes under consideration. The effects of the leaching action are changed, as the experiments of Fricke, Haselhoff, and König[5] have proved. While irrigation with water containing sodium chlorid results in an increased removal of calcium, magnesium, and potassium, yet from water containing magnesium chlorid, the calcium, potassium and sodium are lost and the magnesium is retained. In irrigation with water containing calcium chlorid, the calcium will be retained by the soil and plants, while considerable amounts of magnesium, potassium and sodium are lost.

In large cities, however, the question of injury from sodium chlorid has still a different side, that is, in its use in thawing street railways. Besides this, coarse salt is strewn on the pavements by many householders. In Berlin, this is forbidden, to be sure, but the police is often deceived by the

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1 Wohltmann, F. Die Wirkung der Kochsalzdüngung auf unsere Feldfrüchte. Landw. Zeit. f. d. Rheinprovinz 1904, p. 46.

2 Weber, C. Kritische Bemerkungen usw.; cit. Bot. Jahresber. 1898, II, p. 301.

3 Otto, R. Über durch kochsalzhaltiges Wasser verursachte Pflanzenschädigungen. Zeitsch. f. Pflanzenkrankh. 1904, p. 136.

4 Ehrenberg, Paul, Einige Beobachtungen über Pflanzenschädigungen durch Spüljauchenberieselung. Zeitschr. f. Pflanzenkrankh. 1906, p. 193.

5 Fricke, Haselhoff, E., u. König, J., Über die Veränderungen und Wirkungen des Rieselwassers. Landwirtsch. Jahrbücher 1893, p. 801.

mixing of salt with sand[1]. The salt used to remove the snow melts and passes into the soil where the street is not asphalted. In the spring the trees start to grow but die during the course of the summer. Here, too, the different varieties display different degrees of resistance[2]. Besides this, the action of a solution of sodium chlorid varies according to whether it is constantly sprinkled on the roots or whether the soil dries out between times. The latter case is the more dangerous one.

Extensive injuries have also been found near volcanoes due to the effect of the vapors. The sulfurous acid occurring in varying amounts in the vapor mixture, and also the hydrochloric acid and hydrogen sulfid, may well be the chief causes of the poisoning. They might also give rise to the destructive effect of *the showers of ashes;* yet this has been ascribed also by some observers to the extensively deposited sodium chlorid. According to Pasquale's reports[3], some of the red and violet colors of blossoms change to blue (Papaver, Rosa and Gladiolus), some remain unchanged (*Viola tricolor,* Convolvulus, Digitalis). The green parts of the plants become brown, during a fall of ashes occurring at the time the trees begin to grow, just as after burning or drying but not scalding. Succulent and leathery leaves did not suffer. Mechanical effects from the showers of ashes, such as a possible stoppage of the stomata, could not be confirmed immediately. They seemed, however, to make themselves felt after some days.

Sprenger[4], who describes the results of the Vesuvius eruption in April, 1906, advocates the same theory as does Pasquale.

Waste Water Containing Calcium Chlorid and Magnesium Chlorid.

These are found abundantly in mine water from hard coal mines, in the mother liquor flowing away from salt works and baths, in factories preparing calcium chlorid, and potassium salts, in the waste waters of ammonium sodium factories, etc. The analysis of the neutral fluid, which flows from the kettles to which the ammonium chlorid obtained in the manufacture of ammonium sodium is decomposed, shows, for example, what amounts come under consideration in these cases. König[5] found in 1 liter, 80.06 g. of sodium chlorid, 56.00 g. calcium chlorid, 1.02 g. sodium sulfate. In other tests, which were strongly alkaline, less of the substances named were found, but, in place of these, sodium sulfate and 3 to 5 g. of free calcium. The changes in composition in the soil have already been considered in the previous section, but it should still be emphasized here that favorable effects have been observed if weak amounts are given temporarily (up to 2.0 g. per liter). The germination of seeds was increased. Raspberries and straw-

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1 Weiss, A. Zeitsch. f. Gartenbau und Gartenkunst. 1894, No. 37.

2 Ritzema Bos, Schädlichkeit des Auftauens der Trambahnlinien mit Salzwasser für die in der Nähe stehenden Bäume. Tijdschrift over Plantenziekten 1898, p. 1.

3 Pasquale, Di alcuni effetti della caduta di cenere, etc. Bot. Zeit. 1872, p. 729.

4 Sprenger, C., Vegetation und vulkanische Asche. Österreich. Gartenzeitung 1906, Vol. VII.

5 Denkschrift, p. 161.

berries were found to be very large and brightly colored on the soil saturated with calcium chlorid. The fruit, however, tasted of calcium chlorid and did not keep well[1].

Barium Chlorid.

This is a comparatively less important element, which is found only at times in the waste waters of hard coal mines. Its poisonous action has been proved by Haselhoff[2] in water cultures of maise and horsebeans. Growth in height was arrested; the leaves wilted and fell. In nature, however, direct injury will occur only rarely, because the sulfurous salts rapidly transform it into insoluble and non-injurious *barium sulfate.*

Waste Water Containing Zinc Sulfate.

König[3] has paid especial attention to the investigations of such waters from *Zinc Blend Mines.* It was proved that the brooks which take up the waste water contained sulfurous *zinc oxide* in solution. An evident retrogression in the yield and in places a very poor growth was noticed on meadows thus watered. The grasses grown on such sterile places, as well as the deformed, bushy beech and maple trees, contained up to 2.78 per cent. of their ash in zinc, while the ash of normal meadow plants did not contain this metal. Vegetation dies in places where zinc ore happens to be deposited accidentally. Only one specific zinc plant (the "white mineral blossom") was still visible. This "mineral copper blossom" contained not less than 11 to 15 per cent. zinc oxid in its ash. It is thus seen how differently the various plants behave and what high concentrations may often be endured. The injuries appear only after a considerable number of years, after the zinc oxid present in very small amounts in the water of the brook has accumulated to considerable quantities. König is justified in concluding from this that the requirement made upon mines by the Concession Department that only clear water be allowed to flow away into the streams is not enough protection to the owners of meadows.

The books supplement the discoveries mentioned, one of which by A. Baumann[4] treats exclusively of the effects of zinc salts on plants and soil; while another, by Nobbe, Bässler and Will[5] takes up injuries due to *arsenic* and *lead* as well as zinc.

It must be emphasized, from the results of Baumann's experiments, that the zinc sulfate in solution is much more injurious to plants than had been supposed up to that time. Small amounts (possibly .1% zinc, that is, 4.4 mg. zinc vitriol in a litre) have been proved absolutely non-injurious in all the plants under experimentation (13 species from 7 families) with the excep-

1 Denkschrift, p. 161.
2 Landwirtsch Jahrbücher 1895, p. 962.
3 König, Untersuchungen über Beschädigungen von Boden u. Pflanzen durch industrielle Abflusswässer und Gase; cit. in Biedermann's Centralbl. 1879, p. 564.
4 Baumann, A., Das Verhalten von Zinksalzen gegen Pflanzen und im Boden. Preisschrift 1884. Landwirtsch. Versuchsstat. Vol. XXXI, Part 1, p. 1.
5 Nobbe, Bässler und Will, Untersuchungen über die Giftwirkung des Arsen, Blei und Zink im pflanzlichen Organismus. Landwirtsch. Versuchsstat. Vol. XXX, Parts 5 and 6.

tion of the radish. Conifers are very resistent. They withstood a solution containing 1 per cent. zinc while the Angiosperms died with even 5 mg. zinc per litre and, indeed, older plants died in general more quickly than did young ones.

The effect of the poison manifests itself by a striking change in color of the diseased plants. Scattered small areas of a metallic lustre on a rusty yellow color appear on the leaves and finally spread over the whole surface. The fact that the zinc attacks the chlorophyll apparatus especially, thereby hindering the work of assimilation, is proved by the observation that seedlings in which the chlorophyll grains are not yet matured as well as plants grown in the dark and fungi behave indifferently to relatively highly concentrated zinc solutions.

Zinc carbonate and zinc sulfate placed in the soil exercise an injurious effect. In themselves, to be sure, they are not injurious although they are soluble in pretty considerable amounts in water containing carbon dioxid, whereby the zinc sulfid is first changed to zinc carbonate. But their dangerous action lies in the transformation which the zinc undergoes in the form of vitriol with the potassium, calcium, and magnesium salts. In this these nutrient substances become soluble and may be wasted away. In poor sandy soils sterility may, indeed, be produced and the injuriousness of irrigation with waste water from zinc smelters lies especially in this removal of the nutrient substances.

The injurious solubility of zinc in the soil depends essentially on the amount of calcium carbonate contained in it. In the presence of this mineral to possibly four times the amount of the zinc sulfid no more zinc will be dissolved. A soil ruined by zinc sulfate can be improved by the addition of substances which render the soluble zinc salts insoluble. Humus has been proved to be splendid and, on this account, fertilization with moor soil can be recommended. In the absence of this, abundant stable manure, clay, or marl may be used. Marl, or calcium, must be given under all conditions.

Tschirch mentions, in regard to injuries due to lead salts, that a peculiar kind of dwarfing is produced. The plants which have received 1 kg. mennig (red oxid of lead) to 2 sqm. of surface remain small and do not bloom (leadnanism)[1]. Devaux[2] found that lead solutions in a dilution of 1-10,000,000 acted injuriously. This metal was fixed by the cell wall and contents.

To purify waters containing zinc sulfate, the use of filtering layers of limestone dust and moor earth could be recommended; insoluble carbonic and humic zinc oxid is formed in them.

Water Containing Iron Sulfate.

The waste water from mines and washeries of sulfur silicate and from hard coal mines, the water which drains from piles of hard coal culm and

[1] Tschirch, A., Das Kupfer vom Standpunkt der gerichtlichen Chemie usw. Stuttgart 1893, F. Enke.

[2] Devaux, De l'absorption des poisons métalliques trés dilués par les cellules végétaux. Compt. rend. 1901, cit Just's Jahresber. 1902, II, p. 353.

the waste water from wire factories usually contains iron sulfate. Besides this, the use of ferrous sulfate as a disinfectant in cesspools should also be taken into consideration. Large amounts of iron sulfid are thus produced which, through oxidation in the air, are transformed into iron sulfate and sulfurous iron oxid.

The ferrous oxid, like zinc from zinc sulfate, is retained by the soil and changed to ferric oxid, while a corresponding quantity of other bases, such as calcium, magnesium, and potassium, combine with the sulfuric acid and are easily washed away. This impoverishment of the soil is accompanied by an increase of magnetic oxid which initiates a souring and choking of the ground. As soon as the bases for the transformation of the iron sulfate are exhausted, the ferrous sulfate remains untransposed, or appears also as free sulfuric acid.

However useful small amounts may be on rich soils (up to 150 kg. per hectare, according to König[1]), since the sulfuric acid, thus set free, must act as a loosening medium, just as injurious will be a continued addition of iron sulfate with constant irrigation of pastures. Experiments show that if acid compounds are given the plants instead of the basic salts which alone favor their growth (iron sulfate is strongly acid) a deterioration of the hay results and a decrease in the yield of milk. The different clovers and sweet grasses (possibly with the exception of *Glyceria fluitans*) disappear gradually from such pastures and sour grasses, the horsetails (Equisetum) and mosses take possession of the soil. An addition of lime water causes the elimination of ferrous hydroxid with the formation of gypsum and it will thus be possible to purify waste water containing iron sulfate by the use of calcium.

Waste Water Containing Copper Sulfate and Copper Nitrate.

Waste water from silver factories and brass foundries is concerned. here. An insight into the composition of such water is given by an analysis of solutions flowing from a brass foundry published by Haselhoff[2]. He found in one liter:

Copper sulfate, 51.619 g; Copper nitrate, 5.298 g; Zinc sulfate, 14.045 g; Ferrous sulfate, 2.422 g; Calcium sulfate, 1.943 g; Magnesum sulfate, 0.459 g; and free Sulfuric acid (SO_3), 30,376 g. This is, at any rate, a very extreme case, for it is one hundred times greater in the individual elements than is the content of the water which flows from copper works and silver factories. For the nature of the injury, however, the amount of the elements is unimportant, since small quantities produce the same effect when used in continual irrigation. The way in which the sulfate and nitrate of the copper salts act on the soil is the same as with zinc and iron salts. Copper oxid is retained in the soil and remains chiefly in the upper surface of the pasture land. The sulfuric acid, which is set free, combines with the calcium, magnesium, and potassium, and these salts, with irrigation, pass

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1 Denkschrift, p. 175.
2 Haselhoff, Landwirtsch. Jahrb. 1892, p. 263 and 1893, p. 848. Denksch., p. 176.

into the subsoil. Aside from the impoverishment in basic nutritive substances the copper sulfate (such plants as grasses, for instance, take up rather considerable amounts of copper and zinc salts) acts finally also as a direct poison so far as cultural experiments in nutrient solutions[1] have demonstrated.

Masayasu Kanda[2] found that, in water cultures of peas, injuries appeared even with 0.000000249 per cent. of copper sulfate. On the other hand, if added to soil in a concentration a million times greater, it acted as a stimulant. The conditions are even more favorable for plants in natural soil. According to Tschirch[3] almost all plants possess some copper since, indeed, all field soils may contain traces of it. The vegetation, on soils to which copper is added abundantly, takes up usually but very little copper, so that the danger of poisoning is not imminent. This theory finds substantiation also in the fact that in the very frequent use of copper sulfate as a spraying substance against parasitic diseases a constant enrichment of the soil takes place without any injuries being demonstrable with certainty. We personally believe, at any rate, that a time will come in which a constant addition of copper will make itself felt as a retardation to vegetation.

The waste water containing nickel and cobalt found near nickel-rolling factories will act in the same way as described above. It may be mentioned here supplementarily that John[4] in 1819, in his book "The Feeding of Plants," had studied sand and water cultures to which solutions of different metallic salts had been added. He proved thereby that sunflowers did not take up copper given them in the form of insoluble copper carbonate, while peas and barley stored up great masses from a soil to which a solution of copper nitrate had been added drop by drop.

The fact that local conditions sometimes make possible a beneficial use of the waste water but at other times cause injurious factors to be felt, prevents our consideration in more detail of the different industries. In this connection the poisonous peculiarity of the soil, due to its power of absorption, plays a principal part. Hattori[5] calls especial attention to this in regard to copper salts.

The injuries due to municipal irrigation with liquid sewage have been mentioned already in the section "Sewage Disposal Fields" (page 364).

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1 Otto, R., Untersuchungen über das Verhalten der Pflanzenwurzeln gegen Kupfersalzlösungen. Zeitschr. f. Pflanzenkrankh. 1893, p. 322.

2 Masayasu Kanda, Journ. College of Science. Tokyo, Vol. XIX, Art. 13.

3 Tschirch, A., Das Kupfer vom Standpunkt der gerichtlichen Chemie, Toxikologie und Hygiene. Stuttgart 1893, Fr. Enke, 8°. 138 p.

4 Müller, Carl, Zur Geschichte der Physiologie und der Kupferfrage. Zeitschrift für Pflanzenkrankh. 1894, p. 142.

5 Just's bot. Jahresber. 1902, Absch. Krankh. Ref. 277.

CHAPTER XIX.

INJURIOUS EFFECTS OF CULTURAL METHODS.

A. Coating Substances.

1. *Tar.* The inside of the framework of conservatories is often coated with tar in order to increase its resistance to great dampness. We are confronted with a long list of complaints that, after setting out the plants in the tarred greenhouses, a blackening and falling of the leaves takes place. I noticed the same phenomena near freshly tarred fences. The conditions found agree in all essentials with those described for asphalt fumes and are explained by the exhalations from the *fresh* tar coating. The injurious results do not appear if the tarring has taken place a few months before the plants are brought into the greenhouses. I found a method used in the vicinity of Berlin which acted as well. The boards and framework were treated with hard coal tar and after this had dried were coated with cement.

An attempt has been made recently to keep the paths in gardens and public parks free from dust by means of a thin layer of tar. The process is much recommended[1] and the experiments made in France and Italy have shown that even paved streets can be treated advantageously in this way. This process necessitates, however, the edging of the path with a strip of galvanized tin 8 to 10 cm. high, since the injurious elements of the tar would otherwise attack the vegetation. This process, which despite its necessary annual renewal is said to be still cheaper than asphalting and less troublesome than oiling, or the treatment of the streets with "Westrumit," must still be tested by further experiments.

2. *Refuse from Gas Works.* According to a report from Mr. Klitzing, at Ludwigslust, where roads on sandy soil have been hardened by the use of such refuse, a dying back of the street trees was caused.

3. *White Lead.* In a case of which I have heard, it was necessary to put potted plants in greenhouses a short time after these had been coated with white lead, and then the unpleasant discovery was made that the plants dropped their leaves.

[1] Das Teeren von Fuss- und Fahrwegen in Gärten und Parks. Der Handelsgärtner, herausgeg. von Thalacker, Leipzig-Gohlis 1906. No. 50.

4. *Oil Fumes.* Korff[1] used lead oxid as an addition to *boiling linseed oil* in order to test experimentally the influence of *oil fumes.* He was led to make these experiments by the injuries which had occurred near a *linseed oil and varnish factory.* Just as in the decomposition of fats by alkali, a mixture of fatty acid alkalies, soap, is produced, a mixture of corresponding lead salts, lead plaster, is formed similarly by the decomposing of fat with lead oxid. In both cases glycerine occurs as a by-product. When the glycerine, or fat, is heated to a high temperature fumes of *akrolein* are formed which smell like scorched fat and quickly pass over, through oxidation, into an akroyl acid which is recognized by its suffocating odor. Yellow red to brown spots are produced in the intercostal fields, or along the edges of the leaves according to the nature of the plant. These increase in size with longer action, spread and actually unite. Most of the cells of the leaf mesophyll, especially of the spongy parenchyma, collapse because of the loss of turgidity. The cell contents contract from the walls and the chloroplasts form greenish yellow to brown masses. Finally the structureless cell contents and walls become brown. The elimination of tannin is especially noticeable in the epidermal cells, the contents of which take on a bluish black color with ferric chlorid. The flesh of apples and pears which have been exposed for 4 hours to the oil fumes has an oily rancid taste.

Since *akrolein,* obtained by boiling glycerin, produced the same phenomena the injuries from oil fumes may in all essentials be ascribed to this substance.

5. *Turpentine Fumes.* Molz[2] made experiments on the effect of *turpentine fumes,* because a case was brought him for observation in which the leaves of grapevines were said to have been injured by the fresh coating of oil in the grape house. The action of turpentine fumes on the grape leaves became noticeable after a half hour in the slight discoloration of the edges and the increased curling; after an hour, apple leaves showed a weakly reddish browning; after three hours, an intense dark red brown discoloration of the upper side. The grape leaves became an olive brown. At times some green areas were found within the brown surface, so that the leaves looked dappled. Rose leaves turned an olive brown; pear leaves, a shiny, blackish gray. Molz suspects the cause to be a process of oxydation produced by "the existence of 'terpentinozone' and its action on the 'bradoxydable' substances of the cell."

6. *Carbolineum.* Like tar, *Carbolineum* is used, on the one hand, as a coating substance for the framework of greenhouses, hot beds, stakes, etc., in order to increase the resistance of the wood to moisture; on the other hand, as a remedy for injuries to trees and a means of destroying injurious insects. The great difference in opinion as to its effectiveness is due in part

[1] Korff, G., Über Einwirkung von Öldämpfen auf die Pflanzen. Prakt. Bl. f. Pflanzenbau u. Pflanzenschutz 1906, Part 6.

[2] Bericht der Kgl. Lehranstalt für Wein- Obst- und Gartenbau zu Geisenheim a. Rh. 1905.

to unsuitable manipulation and also because "carbolineum" is a general term; the different kinds have different compositions and effects according to the factories producing them.

In general, all that has been said of tar holds good for the use of carbolineum as a coating substance. If plants are brought into rooms where the carbolineum coating has not dried sufficiently, they suffer and, at times, show symptoms resembling those produced by asphalt fumes. Thus, for example, Zorn in Hofheim (Taunus) reports[1] that the leaves of strawberry plants set out in hot beds of which only the outer side had been painted with carbolineum, became a peculiar brown, very shiny and curled. Under the subject of coating the tips of grapevine stakes, a "Chronique agricole"[2] calls attention to the fact that even when such stakes have been painted in the winter and the young shoots of the grapevine have already overgrown the painted part in spring, unpleasant phenomena can still occur. Some berries on the bunches which touched the saturated spots were found with blackish brown spots and had a slightly tarry taste. Also the saturated parts of the stake were found less resistant to fungi than those treated with copper vitriol. It was noticed in a peach trellis which was painted in the autumn and exposed to the weather for the whole winter that, nevertheless, in the spring after every rain the youngest tips of the shoots looked as if they had been burned. Such occurrences are by no means uncommon. It is the vaporizing phenol and similar bodies which cause the injury.

Since 1899 carbolineum has been used extensively as a remedy applied directly to fruit trees[3]. As to the results, we find some unusually laudatory opinions, some very harsh ones. The reason for this lies, on the one hand, in the difference in carrying out the experiments; on the other, in the varying composition of the substance which is a mixture procured in the production of tar from hard coal and charcoal. If the tar which is produced in the manufacture of gas from hard coal together with the illuminating gas, coke and ammonia water, is reheated in a distilling apparatus up to a temperature of 150 degrees C., so-called light oil is obtained; between 150 degrees and 210 degrees C. middle oil; between 210 degrees and 270 degrees C. heavy oil, and between 270 degrees and 450 degrees C. anthracene[2].

The pitch remains in the oven. Wood tar behaves in much the same way. In preparing carbolineum the oils above named are used since they are mixed in definite percentages and decomposed with kolophonium, asphalt, boiled linseed oil, etc. Aderhold[4] states that, at the present time, possibly 80 carbolineum factories furnish the trade with 200 to 300 varieties. The distillation experiments made by Scherpe in the Biological Institution of Agriculture and Forestry with 25 varieties proved that often the (especially injurious) light and middle oils were absent and the heavy and

1 Praktischer Ratgeber im Obst- and Gartenbau 1905, No. 51.
2 Chronique agricole du canton de Vaud 1892, No. 10.
3 Mende, O., Zur Obstbaumpflege. Gartenflora, 1906. No. 1.
4 Aderhold, R., Karbolineum als Baumschutzmittel. Deutsche Obstbauzeitung (Ulmer-Stuttgart) 1906, Part 22.

anthracene oils alone were present, while in other varieties the opposite was found to be true. Accordingly, the results in treating wounds were very different. While normal overgrowth occurred with some, with others there was a very visible increase in the size of the wounds due to the dying back of their edges.

But, aside from this, the carbolineum as a means of closing wounds, even in the viscid varieties abounding in pitch and asphalt, does not stand comparison with plain hard coal tar, for Aderhold has observed that a few weeks after the painting, fungus species had already appeared on the carbolineum surfaces. Since the painted surface may also crack, under the influence of the atmosphärilia, such fungi have a good opportunity of penetrating into the wood.

In regard to the very fluid kinds of carbolineum, that is, those rich in light and middle oils, which are warmly recommended for coating trees attacked by red aphis and scale[1], the promptness of their action in killing insects is unmistakable, but its protection is not permanent. The recolonization of the painted wounds by red aphis has been repeatedly confirmed. To this should be added, however, the often observed injury to the buds which cannot be avoided in painting or spraying the trees and which is to be ascribed especially to the vaporization and direct action of the light oils. Therefore, the substances should be diluted. It is advisable to use the commercial carbolineum varieties which are soluble in water and to add them to lime water up to about 20 per cent.[2]; even an addition of 10 per cent. acts favorably[3].

An action directly favoring growth is said to have been observed in trunks thus coated[4], and also the increase of the chlorophyll content of the painted bark has been microscopically determined in Brunswick with the use of a definite brand[5]. We believe that this result is due to the fact that in coating smooth barked trunks tears are frequently produced in the bark which must be overgrown subsequently. An increased bark activity in the overgrowth walls has also been proved in common scarification.

The use of this substance as a coating for trees is advisable only during the dormant period and in fact with some tested brand. "Schacht's fruit tree Carbolineum" (containing 20 to 30 per cent.) has been repeatedly recommended[6]. We would never advise spraying in summer. As a means of closing wounds we would prefer coal tar because not only Aderhold's discoveries, but also experiments made by Schweinbez[7] in Hohenheim, and our own have shown no advantage in the use of carbolineum. Its recom-

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1 Baumann, R. Geisenheim. Prakt. Ratgeber 1905, p. 459.
2 Praktischer Ratgeber im Obst- und Gartenbau 1906, No. 49.
3 Praktische Blätter für Pflanzenbau und Pflanzenschutz, herausg. v. Hiltner. 1906, November.
4 Gartenflora 1906, No. 3.
5 Graef, Über Karbolineumversuche im Jahre 1906, Prakt. Blätter f. Pflanzenbau und Pflanzenschutz, 1907, Part 3.
6 Steffen in Prakt. Ratgeber 1906, p. 23.
7 Vom Karbolineum. Gartenflora 1906, p. 22.

mendation as a remedy for chronic gummy exudations is based at least upon self-delusion if not the exigencies of advertising.

Schweinbez holds the same opinion of the related substances "Tuv", "Dendrin", "Baumschutz", "Neptun".

7. *Lyzol.* Formerly lysol had its enthusiastic adherents and doubters just as carbolineum has them now. The *Lysolum purum* of Schölke and Mayr in Hamburg, introduced into trade about the end of the 80's of the last century, is a transparent, brown, syrup-like fluid which remains dissolved and perfectly clear in pure water, and has been extensively used as a means of disinfection. In introducing it, it was said that, according to experiments, 3g. of lysol to a litre of liquid was enough "to destroy, in 15 to 20 minutes, bacteria in all their developmental forms, if suspended in liquids." We are concerned here with a solution of tar oils in neutral soap and, indeed, with the light tar oils (cresol), for they volatilize almost entirely between 187 and 200 degrees[1]. In contrast to other commercial products, like creoline, cresoline, Little's Soluble Phenyle, which, as solutions of resin or fatty soap in tar oil only form emulsions with water and usually give off carburetted hydrogen oil (Ethylene), when diluted, lysol has the advantage, at any rate, of complete solubility in water, but shares with the above preparations an injurious effect on the tissues of plants. It was used in horticulture mostly as a spraying substance for leaf lice, thrip, black fly, and other injurious insects. Otto's[2] cultural experiments, made soon after the introduction of the substance, showed that 0.5 per cent. lysol solution, the one commonly used for disinfection, proves to be a severe poison for plants if added to the soil, even if it does not come directly in contact with the seeds or seedlings. With direct action, even in a much more diluted form, it attacks uncommonly sharply the roots of water cultures. It was used in a 0.25 to 0.5 per cent. solution as a protection against leaf lice. In this, however, it kills only some of the leaf lice, the majority of which die only with a 2 per cent. solution; the plants were then so blackened and injured that they could not be considered capable of further life.

8. *Carbolic Acid, Amylocarbol, and Sapocarbol.* The amylocarbol is a mixture of soft soap, fusel oil, and pure carbolic acid. Sapocarbol is saponified carbolic acid.

All substances containing carbolic acid are dangerous and usually directly fatal for plants. In Fleischer's experiments[3] with the above preparations, the sapocarbol in one per cent. solution was effective for leaf lice without any injury to the leaves from the spraying, with a few exceptions. In dilutions which completely kill the leaf lice, *Pinosol* and *Creolin* act injuriously since both can only be emulsified in water. The ***Antinonnin,*** the

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1 Zeitschr. f. Pflanzenkrankh. 1891, p. 185.

2 Otto, R., Über den schädlichen Einfluss von wässerigen, im Boden befindlichen Lysollösungen usw. Vorl. Mitt. Zeitschr. f. Pflanzenkrankh. 1892, p. 70ff.

3 Fleischer, E., Die Wasch.- und Spritzmittel zur Bekämpfung der Blattläuse, Blutläuse u. ähnlicher Schädlings usw. Zeitsch. f. Pflanzenkrankh. 1891, p. 325.

potassium salt of *Orthodinitro-Cresol* is more injurious to plants, according to Frank's experiments[1], than to leaf lice and other animal parasites.

9. *Refuse from Lactic Acid Factories.* To those injuries we will add a case which we owe to a report from Mr. Klitzing of Ludwigslust. He noticed that the refuse from a factory which produced *lactic acid* from maize and potatoes, for the treatment of leather, caused the death of plants.

10. *Calcium arsenite.* The arsenic solutions which are being accepted more and more as a means for combating insects are used as a rule in the form of Schweinfurter green, or calcium arsenite. Injuries to the leaves have been observed in aqueous solutions as also in lime water or Bordeaux mixtures, or sodium arsenite calcium solutions. In general we would refer to the special books on the subject[2].

11. *Hydrocyanic acid.* Fumigation with hydrocyanic acid has recently been accepted as a modern method of combating animal parasites in plants and has been developed especially in America. It may be said in general, in opposition to individual complaints of injuries to plants, that these should not prevent the use of this substance[3]. Townsend confirmed, for dry seeds, that the germinating capacity does not suffer if the action of the hydrocyanic gas is not continued longer than is necessary for killing animal life. A longer treatment, however, causes considerable injury. Moist seeds suffer more quickly and lose their power to germinate.

12. *Copper solutions.* These come under consideration here only in so far as their injuriousness is concerned. Their usefulness as fungicides, which will be considered in the second volume of this book, depends, in our opinion, chiefly upon the fact that the fungi give out ferments which dissolve the copper salts dried on the plant parts and thus poison themselves. Bordeaux mixture which, without doubt, is of great importance as a means for fighting fungi, may primarily favor growth, as its enthusiastic advocates would like to prove, but it cannot be acknowledged as a promotor of growth.

Opinions as to whether the copper can penetrate through a normal cuticle in all plants are not unanimous. According to Bouygues[4] this is not the case. Rumm[5] also could not prove the existence of copper in the tissue of sprayed leaves and believes that the favorable action can be traced only to the chemico-tactic stimulus. The electric currents, resulting from it, are said to cause the favorable effect in the leaf tissue. The question whether copper can react on the interior of any part of a plant and how, cannot be decided universally but must be taken into consideration case by case. Old cuticule, provided with a thick wax coating, will possibly not be attacked

[1] Krankheiten der Pflanzen 1895, Vol. I, p. 329.

[2] Hollrung, M., Jahresbericht auf dem Gebiete der Pflanzenkrankh. Berlin, Paul Parey. Published since 1898. Hollrung, M., Handbuch der chemischen Mittel gegen Pflanzenkrankheiten. Berlin 1898. Paul Parey.

[3] Townsend, W. O., Über die Wirkung gasförmiger Blausäure usw. Bot. Gaz. XXXI; cit. Bot. Jahresber. 1902, I, p. 354.

[4] Bouygues, H., La cuticule et les sels de cuivre I; cit. Centralbl. f. Bakt. usw. 1905, N. 24.

[5] Rumm, C., Zur Frage nach der Wirkung der Kupferkalksalze usw. Ber. d. Deutsch. Bot. Ges. 1893, p. 445.

while a young leaf can suffer. In older leaves, however, injuries may also occur in one case and not in another; the cuticle covering may be broken by atmospheric action (late frost) and the copper solution may remain for some time in these tears. Finally, the specific sensitiveness of the plant variety is decisive, as will be shown in later examples.

The first doubt as to the peculiarity of copper mixtures for favoring growth arose from the results of some spraying experiments made in 1891[1]. An arrestment in the development of potato plants could be proved as compared with unsprayed plants which remained healthy. The considerable amounts of starch and chlorophyll contained in leaves treated with copper which are considered as an indication of favoring growth were traced by Schander to the effect of the shade caused by the calcium copper coating[2]. Ewert confirms the effect of shading but calls attention to the fact that this may not be the only arresting factor[3]. Through the effect of the copper substances, especially Bordeaux mixture, *stoppages occur in the transference of the assimilates.* The considerable amounts of starch and protein, here observed, are not the results of increased assimilation which, as has been proved, is repressed together with transpiration and respiration, but is the action of arrested transpiration. This point of view which we represent presupposes, at any rate, that copper actually enters the plant and this theory is substantiated by the fact that scientists who do not assume a penetration of the copper still find copper reactions in a number of their experiments (Frank and Krüger). Besides this, Ewert has also proved the presence of copper in plants sprayed with Bordeaux mixture. Later we will quote notes from Schander's work as to the way in which the copper is taken up.

In my opinion, the copper, entering through wounds, or through the epidermis of plants treated with copper mixtures, is combined at once with the proteins of the protoplasm and thereby reduces cell-life. Since spraying does not represent a complete wetting of all the leaf surface, certain areas remain healthy, between injured ones, and these must show an increased growth activity. This makes itself evident at times with an abundant supply of light and moisture, in the formation of *intumescences.* I described the first case of this kind in potatoes[4]. Later v. Schrenk[5] observed intumescences on cabbage plants as a result of their treatment with copper-ammonium-carbonate, copper chlorid, copper acetate, copper nitrate and copper sulfate. Very recently Muth[6] has observed a very strong formation of intumescences in grape leaves after a treatment with copper.

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1 Sorauer, P., Einige Beobachtungen bei der Anwendung von Kupfermitteln gegen die Kartoffelkrankheit. Zeitschr. f. Pflanzenkrankh. 1893, p. 32.

2 Schander, E., Über die physiologische Wirkung der Kupfervitriolkalkbrühe. Inaug.- Diss. Berlin 1904 und Landwirtsch. Jahrbücher 1904, Parts 4 and 5.

3 Ewert, Der wechselseitige Einfluss des Lichtes und der Kupferkalkbrühen auf den Stoffwechsel der Pflanze. Landwirtsch. Jahrbücher 1905, p. 233.

4 Zeitschr. f. Pflanzenkrankh. 1893, p. 122.

5 Schrenk, H. v., Intumescences formed as a result of chemical stimulation. Sixteenth annual report Missouri Botanical Garden. May, 1905. Special reprint.

6 Muth, Franz, Über d. Beschädigung d. Rebenblättern durch Kupferspritzmittel. Mittel. d. Deutsch. Weinbauvereins I. Jahrg. No. 1, p. 9.

Such effects may be produced if the tissue is partially poisoned but does not actually die. They may also occur, however, when death actually takes place in which case the dead tissue areas in many plants fall out of the leaf, causing *perforation*. Such cases have recently been described by Schander[1]. In connection with this, it is mentioned that Fuschia and Oenothera secrete acids which dissolve small amounts of copper hydroxid. Alkaline secretions have also been found (*Phaseolus multiflorus*), or the copper is dissolved not by secretions of the leaf but simply by the atmosphärillia, especially with continued wet weather.

Ruhland[2] declares, on the other hand, that the assumption of a dissolving of the copper by leaf secretions has no justification, and that this can be ascribed only to the atmosphärillia.

Reports as to the injury to foliage from spraying with copper have appeared as the process has been more generally used. In 1891 it was observed in fighting *Peach rot* that, after using Bordeaux mixture, not only the leaves and blossoms fell, but the young wood also was injured[3]. The Amygdalaceae and especially peaches have been found to be especially sensitive. Bain[4] showed in his experiments with apple, grape and peach leaves that this is connected with the specific sensitiveness of the protoplasm. He says that the peach leaf is able to dissolve copper oxid by a substance secreted on its upper surface. Young leaves suffer most. The injured part of the leaf is then cut off by a cork layer and thrown off (Shot disease, which Aderhold[5] has also described for the cherry). Severely diseased peach leaves fall but the apple leaf, as well as the grape, possesses the ability to continue assimilation by means of the remaining lamina.

Fig. 169. An apple with brown spots and cracks. (After Hedrick.)

According to Hedrick's[6] more recent studies, peaches, apricots, and Japanese plums are the most sensitive fruit trees, while the common plum is not affected more severely than the pear, apple or quince. The different varieties behave differently. The most highly cultivated examples, with the

1 Loc. cit.
2 Ruhland, W., Zur Kenntnis der Wirkung des unlöslichen basischen Kupfers auf Pflanzen usw. Arbeiten d. Biol. Abt. f. Forst.- u. Landwirtsch. beim Kaiser. Gesundheitsamt Vol. IV, 1904, Part 2
3 Report of the Secretary of Agric. for 1891, Washington 1892, p. 364.
4 Bain, S. M., The action of copper on leaves, etc. Agric. Exp. Stat. of the University of Tennessee, 1902, Vol. XV.
5 Aderhold, R., Über **Clasterosporium carpophilum** usw. Arb. d. Biolog. Abt. d. Kais. Gesundheitsamtes, 1902, Part 5.
6 Hedrick, U. P., Bordeaux injury. New York, Agric. Exp. Stat. Geneva. Bull. No. 287, 1907.

most watery leaves, suffer most. *Atmospheric conditions* have great influence, and on them depends the more delicate, or coarser development of the leaves and especially of their cuticule. The year 1905 furnished the best proof in New York State. Its warm, misty, spring weather left the foliage very tender. Many apple growers declared that there was greater injury in that year than benefit from spraying with Bordeaux mixture. Hedrick cites examples in which spraying was unusually injurious when the following weather continued moist, while 8 days later after dry weather had set in the spraying did not have any bad effects.

Fig. 170. Young apples with one-sided malformation, after spraying with Bordeaux mixture. (After Hedrick.)

Fig. 171. Cross-section through the bark of a Baldwin apple injured by spraying with Bordeaux mixture. (After Hedrick.)

We have borrowed from the above mentioned author some illustrations of fruit and leaves which have been injured by spraying. The injury at first appears on the fruit in the form of small brown specks which spread to extensive rust markings (Fig. 169). If these injuries to the upper surface occur during the period of swelling, the growth of the fruit may become irregular (Fig. 170), or gapping cracks may be produced in young apples. Fruit thus injured becomes mealy and easily decays.

Microscopic investigation of the brown spots shows that the cuticle covering with its wax coating is destroyed (Fig. 171). The walls of the adjacent epidermal cells and the exposed flesh become greatly thickened and

give a cork-like appearance. They cannot respond any longer to the swelling of the fruit, which, therefore, cracks. The wound cork formed in the cracks, together with the tissue killed by the Bordeaux mixture, then causes the peculiar "rust figures" shown in Fig. 169. The amount of injury increases with the tenderness of the skin, which shows the initial stages of browning, as a rule, around a hair or a stoma. With the increasing age of the fruit, the hairs are thrown off normally and lenticels are produced instead of stomata. In this the wax coating is thickened and the fruit becomes immune to the poisonous copper. Brown spots may be produced also on the leaves which at times repture (Fig. 172). Naturally the blossoms suffer most severely. It can be assumed with certainty that in these blossoms the copper unites with the cell contents. Hedrick's remark that a considerable addition of lime scarcely decreases the injury is worthy of consideration in regard to the preparation of the Bordeaux mixture. This is treated more thoroughly in the second volume of this book (page 521).

Fig. 172. Apple leaf with dead spots and holes in the tissue, after spraying with Bordeaux mixture. (After Hedrick.)

All that is true of calcium copper mixtures holds good to a higher degree in the *Azurine* in which ammonia is used to neutralize the copper vitriol. Pure deep blue solutions are produced, according to the amounts of ammonia used, such as "*Bouille Celeste*" and the "*Azurine Siegwart*," or especially with greater dilution basic copper compounds remain as a precipitate, as is found in the "*Crystal-Azurine Mylius*." The more ammonia used, the greater is the danger of burning the leaves[1].

Anaesthetica.

In considering the so-called "*forcing with ether*," that is to say the process of exposing the plants to ether vapor in order to hasten their growth,

[1] Kulisch, P., Über die Verwendung der "Azurine" zur Bekämpfung der Peronospora. Landwirtsch. Z. f. Elsass- Lothringen 1907, No. 26.

we must take up also the subject of anaesthetica. The favorable results which can be obtained, especially in the early forcing of lilacs, by a proper use of this method are certain beyond doubt; but with an incorrect use disadvantageous results become noticeable. The action of ether, chrom-ether chloroform, nitrous oxid, morphine, cocaine, etc., as proved by repeated experiments, consists in retarding the complete development of protoplasmic activity. If, in this, the protoplasm undergoes a continued injury to its physical or chemical structure, death follows; otherwise, the plant gradually returns to the normal activity.[1]. Naturally the effect depends upon the condition of the protoplasm. Thus, Coupin[2] has proved that even an atmosphere saturated with chloroform and ether can exert no influence on the protoplasm of seeds in a dormant stage. If, however, their life activity has been aroused by moistening very small amounts (.00037) are enough to cause injury. Yet the figures given here should not be considered as a standard, for aside from the individuality of the species even plants of the same species can develop a different power of resistance by self adjustment. Thus, for example, Townsend[3] states that spores of Mucor and Penicillium ripened under a strong ether atmosphere germinated and produced spores just as quickly as when they had germinated in an atmosphere free from ether. The same observer mentioned that here and in other poisons very weak doses act as a stimulus and shorten the period of germination, while stronger doses are injurious.

The observations of Markowine[4] give an insight into the kind of action. He draws the conclusion from his experiments that, in the long continued action of anaesthetizing vapors, *respiration becomes considerably increased.* He found that, under the influence of alcohol vapor, the respiration of etiolated plants was increased more than one and a half times; ether acted still more strongly.

We may assume here a specific response to stimulation. Behrens[5] also holds this theory. He would like also to consider as a response to stimulation the hastened germination of seeds after mechanical injury which Hiltner ascribes to the facilitated absorption of water. Behrens bases his theory on experiments with injured seeds in which the wounded places were covered at once with colophoneum wax. Although the absorption of water by these grains did not seem increased as compared with normal grains, there appeared, nevertheless, an appreciable increase of growth. Experiments with filing and other intentional injuries to hard shelled seeds proved, however, that even the mechanical facilitation of the entrance of water favors germination.

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[1] Kaufmann, C., Über die Einwirkung der Anaesthetica auf das Protoplasma und dessen biologisch-physiologische Eigenschaften; cit. Just's Jahresber. 1900, II, p. 301.

[2] Coupin, H., Action des vapeurs anesthésiques sur la vitalité des graines séches et des graines humides; cit. Just's Jahresber. 1900, II, p. 301.

[3] Townsend, C. O., The effect of ether upon the germination of seeds and spores; cit. Just's Jahresber. 1899, II, p. 142.

[4] Markowine, N., Recherches sur l'influence des anesthésiques sur la respiration des plantes; cit. Just's Jahresber. 1899, II, p. 143.

[5] Behrens, Bericht d. Grossherzogl. Badischen Landwirtsch. Versuchsanstalt Augustenberg f. d. Jahr. 1906.

INJURIES DUE TO FERTILIZERS.

1: *Chili saltpetre.* Unfavorable secondary and subsequent effects have often been observed with the use of Chili saltpetre. The cause lies in part in the presence of potassium-hyperchlorate. Numerous cultural experiments have proved that grain is especially sensitive and shows striking injuries with 2 per cent. hyperchlorate, while alfalfa, peas and mustard could endure this concentration. In rye, a deformation of the plant was observed when grown as a late crop[1]. Vegetables, requiring hoeing, and sugar beets were not injured by 2 per cent. hyperchlorate to 200 to 500 kg. saltpetre per hectar[2]. Jungner and Gerlach[3] describe the formal changes in wheat and rye seedlings as follows: The primordial leaf remains for some time partially rolled and encloses the secondary leaf so firmly that it loosens its tip only with difficulty and consequently forms a loop, or knot, in which it is folded crosswise and rolled about its own axis; it finally may even tear. At the same time a yellowing of the leaf tip takes place and a considerable reduction in the elongation of the whole plant. Retardation of germination will occur, in fact, according to the amount of hyperchlorate present. This has not been observed with weak doses. The forming of loops by leaves because of the retention of their tips in the sheath of the next older leaf seems to be a marked characterization of grain when poisoned with hyperchlorate. It is, however, not limited to grain, since similar phenomena occur in *Tylenchus devastatrix*[4].

Dafert and Halla[5] describe a case of the appearance of free iodine in Chili saltpetre which thus gave the odor of iodoform. The saltpetre contained 0.31 per cent. $KCLO_4$ and 0.04 per cent. KIO_3. In such cases, however, the danger is slight in general agriculture, since it is only necessary to expose the sacks of Chili saltpetre to the air in order to evaporate the iodine. Voelker[6], among others, has showed that the iodids of manganese, potassium, sodium and lithium act injuriously while the oxids are proved to be favorable. In connection with his earlier experiments by which he proved the injuriousness of larger amounts of sodium iodid and bromid and of lithium chlorid, while, on the other hand, an advance in germination was found when the seeds were moistened with more dilute solutions, Mazé[7] concludes that the

[1] Ullmann, Martin, In welchem Grade ist Kaliumperchlorat ein Pflanzengift? Die Regelung des Verkehrs mit Chilisalpeter. Meffe 1901. Cit. Centralbl. f. Agrikulturchemie 1903, Part 7.

[2] Stoklasa, Beiträge zur Kenntnis des schädlichen Einflusses des Chilisalpeters auf die Vegetation. Z. f. d. landwirtsch. Versuchswesen in Österreich 1900, p. 35.

[3] Jungner und Gerlach, Versuche mit Kaliumperchlorat. Jahresber. d. landw. Versuchsstation in Jersitz bei Posen 1897-98, p. 29.

[4] Krüger, Fr. u. Berju, G. Ein Beitrag zur Giftwirkung des Chilisalpeters. Centralbl. f. Bakt. II, 1898, Vol. IV. p. 674.

[5] Dafert, F. W., u. Halla, Ad., Über das Auftreten von freiem Jod im Chilisalpeter. Z. f. d. landw. Versuchswesen in Österreich 1901.

[6] Voelker, A., über den Einfluss von Mangansalzen sowie von Jodiden und Oxyden von Mangan, Kali, Natrium und Lithium auf Gerste und Weizen. Journ. Royal. Agric. Soc. of England, Vol. 64 and 65; cit. Centralbl. f. Agrikulturchemie 1905, p. 715.

[7] Mazé, Einfluss der in den Pflanzen in geringer Menge enthaltenen Mineralstoffe auf das Pflanzenwachstum. Biedermann's Centralbl. f. Agrikulturchemie 1902, p. 686.

cell needs stimulation by such salts for the complete development of its functioning. Aso[1] has made similar discoveries as to the injuries due to stronger concentrations of sodium fluorid and the favoring of growth by very weak concentrations. Suzuki[2] has also found this to be true of potassium iodid. Similar discoveries have often been observed by others. Miani[3] also reports the favorable action of copper solutions.

2: *Superphosphate.* We should briefly consider the *breaking down of phosphoric acid* in superphosphate and Thomas meal in many soils which are rich in calcium and ferric oxid. In sour, marsh soil and sour meadow soil, rich in humus, retention of the phosphoric acid in a soluble form predominates since water, carbon dioxid, humic acid and some salts act as solvents. In sandy soil containing humus but not acid the process of solution is approximately held in equilibruim with the process of transforming the dissolved phosphoric acid into less soluble forms but in loamy soils, containing calcium and iron, the process of decomposition preponderates, that is, the process of transforming the soluble phosphoric acid into phosphates which are dissolved with difficulty. Under such circumstances the use of Thomas meal in the spring would not be advisable.

3: *Gas phosphate.* Rhodanammonium is found in different amounts in the refuse of gas factories. This has attained a heightened agricultural significance since a fertilizer, containing nitrogen, has been produced by the purification of illuminating gas with superphosphate, and has been introduced in trade as *"gas phosphate."* The acid phosphate has taken up the ammonia from the stream of illuminating gas but at the same time has retained the Rhodanammonium. Because of the repeatedly proven poisonous quality of this compound the purification of the fertilizer has been attempted by washing the gas phosphate with a concentrated solution of ammonium sulfate in which the Rhodanammonium compounds are easily soluble. The amount of Rhodan compounds contained could be reduced thereby to 0.9 per cent. and, consequently, the direct use of this fertilizer has been recommended. It is, in fact, distinguished by its large content of phosphoric acid and nitrogen.

The experimental results are contradictory in that favorable effects have been observed on sandy soil and unfavorable effects on loamy soils. This brought about the supposition that, in sandy soils, a more rapid decomposition of the Rhodanammonium into ammonia, nitric acid and sulfuric acid occurs whereby the poisonous effect is repressed. This hypothesis is confirmed by other experiments which demonstrate that in using the fertilizer some weeks before seeding, no injuries appear, while severe losses take place when it is used simultaneously with seeding. The same result was found in using dust from a blast furnace containing 1 per cent. Rhodanammonium.

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1 Aso, Bull. Coll. Agric. Tokyo; cit. Bot. Jahresber. 1902, p. 353.
2 Suzuki, S. ibid.
3 Miana, D., Über Einwirkung von Kupfersulfat auf das Wachstum lebender Pflanzenzellen. Ber. d. Deutsch. Bot. Ges. 1901, Part 7.

The recent experiments of Haselhoff and Gössel[1] leave no doubt as to the poisonous effect of Rhodanammonium, the decomposition of which even in sandy soil does not take place so easily as earlier examples seemed to prove. Even a very small amount, such as 0.0025 per cent., produces a considerable delay in germination and since the purified gas phosphate still contains 0.76 per cent. Rhodanammonium the above named scientists could not recommend it at all as a fertilizer, even with the difficult solubility of phosphoric acid.

4: *Ammonium sulfate.* In connection with this, a case of injury due to ammonium sulfate should be mentioned here, which was previously unknown. A car full of plants (Azaleas), when opened, showed that the leaves had been partly blackened as if from ammonia fumes. Subsequent investigations showed that the car had been used previously for the transportation of ammonia sulfate. Experiments made immediately proved that free ammonia developed in the presence of calcium. In the same way, fresh ammonium sulfate which has not been sufficiently dried and neutralized can develop ammonia and as in the case described in the section on ammonium fumes this can adhere to the walls and subsequently act injuriously.

5: *Calcium nitrid.* This recent product of our fertilizer industry still gives rise to repeated complaints. *Calcium carbid* used primarily in the production of the very bright illuminating gas, acetylene, and obtained from the interaction of lime and carbon in an electric oven is exposed in hermetically sealed iron mufflers to the action of nitrogen with intense heat and then furnishes the calcium nitrid as an unpurified calcium cyanamid with possibly 20 to 24 per cent. nitrogen. This calcium nitrogen, or calcium cyanamid, has the peculiarity of giving off all its nitrogen in the form of ammonia when heated with water under pressure. By passing the ammonia through sulfuric acid it is possible to produce the valuable fertilizer, ammonium sulfate. The "calcium nitrid" ($CaCN_2$) contains about 20 to 21 per cent. nitrogen; 40 to 42 per cent. calcium and 17 to 18 per cent. carbon, besides impurities of silicic acid, clay, traces of phosphoric acid, etc. By removing the calcium, there are produced Cyanamid (CN,NH_2) and the homologous Dicyandiamid $[C_2N_2(NH_2)_2]$.

The calcium, present in the calcium nitrogen, which acts as a strong alkali, is partly free and partly combined in the form of calcium cyanamid. For this reason it should not be brought into contact with supersulfat because the phosphoric acid would then be made insoluble. The rules for its use are approximately as follows:[2]—The quantity used per hektar according to the constitution of the field, is 150 to 300 kg. corresponding to 30 to 60 kg. nitrogen. To avoid the loss in dust the calcium nitrid is mixed with twice the amount of dry earth. This should be spread 1 to 2 weeks before the

1 Haselfhoff, E., u. Gössel, F. Versuche über die Schädlichkeit des Rhodanammoniums für das Pflanzenwachstum. Zeitschr. f. Pflanzenkrankh. 1904, p. 1. Bibliography here given.

2 Brahm, Der Kalkstickstoff und seine Verwendung in Gartenbau und Landwirtschaft. Gartenflora, Berlin, 1906, Part 10.

sowing of the seed and the fertilizer must be covered at least 3 to 5 inches so that the soil can take up the ammonia freed by the action of the soil moisture and thus be nitrified.

The production of the ammonia from the calcium nitrate takes place by means of bacteria[1].

The fertilizing experiment, carried out in vegetating vats, has shown the possibility of obtaining the same fertilizing action with calcium nitrid as with saltpetre nitrid and ammonia nitrid. In all field experiments, made as yet, the calcium nitrid has developed about 74 per cent. of the action of the saltpetre nitrid[2].

The agriculturalist will cause great injury if he sows his seed soon after scattering the calcium nitrid. Usually only those grain seeds will then sprout which lay on the ridges of the furrows. If the first shock is overcome, the abundant supply of ammonia manifests itself in the especially dark green of the plants. The injury consists of a drying of the leaf parenchyma and a poor root development[3]. The calcium nitrid may not be used as a top dressing any more than as a direct fertilization before seeding. This substance acts unfavorably on certain soils even if it is hoed under according to rule. Remy[4] found the most favorable action on clayey soils. On sandy soil, however, action was considerably slower and the directly injurious effect on germination much more persistent. Only three months after fertilization did he find that the injurious effect in the sandy soils had disappeared. All soils, tending to the formation of acids, retard the normal formation of ammonia. Tacke has proved that, on acid soils, the transformation into ammonia is so hindered that fertilization of marshes with calcium nitrid must be omitted there. On the other hand, when a great deal of calcium is present in the soil, the ammonia formation can take place so rapidly that extensive losses arise from the vaporization of the ammonia. On high moor soils poisonous action is found which, according to Gerlach, may be traced back to the fact that, with the decomposition of the calcium cyanamid and the deposition of the calcium, considerable amounts of the poisonous dicyanamid are produced within a few days.

The conversion of the ammonia into ammonium sulfate, which thus overcomes these disadvantages, is useless for agriculture, since the cost of the nitrogen would thus become too great.

A still newer fertilizer is associated with this "calcium nitrid," "the nitrogen calcium" which is free from cyanamid compounds and contains 22 per cent. nitrogen; 19 per cent. carbon; 6 per cent. combined chlorin; and 45 per cent. calcium. Böttcher's[5] experiments have shown that with this, how-

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1 Löhnis, F., Über die Zersetzung des Kalkstickstoffs. Centralbl. f. Bakt. 1905, II, Vol. XIV, p. 87. Behrens, J., Versuche mit Kalkstickstoff. Bericht der Grossherzogl. Bad. landw. Versuchsanstalt Augustenberg 1904, Karlsruhe 1905, p. 36.

2 Gerlach u. Wagner, P., Gewinnung u. Landwirtschaftliche Verwendung des Salpeterstickstoffs. Verhandl. d. Winterversammlung 1904 d. Deutsch. Landwirtsch. Ges. Jahrb. d. D. L. G. Vol. 19, p. 33-39.

3 Perotti, R., Über die Verwendung des Calciumcyanamids zur Düngung. Staz. sper. agrar. Ital. 1904, Vol. XXXVII; cit. Centralbl. f. Agrikulturchemie 1905, p. 814.

4 Blätter f. Zuckerrübenbau, 31 May, 1906.

5 Deutsche landw. Presse 1906, No. 34.

ever, the same precautionary measures are necessary as with calcium nitrid. It may not be used immediately before seeding, nor as a top dressing, because it is then injurious[1].

In regard to the Ammonia nitrid, we should not forget to call attention to the fact that it may also become injurious under conditions in which the nitrifying bacteria do not act sufficiently. For heavy soils, which contain more water and, therefore, dissolve the ammonia more abundantly there is no danger, but in sandy soils the retarded solubility may lead to direct phenomena of corrosion[2].

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[1] Blätter, f. Zuckerrübenbau 1906, No. 10.

[2] Mazé, Untersuchungen über die Einwirkungen des Salpeterstickstoffs und des Ammoniakstickstoffs auf die Entwicklung des Mais. Annal. agron. t. 26; cit. Centralbl. f. Agrikulturchemie 1901, p. 588.

SECTION V.

WOUNDS.

CHAPTER XX.

WOUNDS TO THE AXIAL ORGANS.

General Discussion.

However much accidental or intentional injuries to the tree trunk may differ, nevertheless, the process of healing always agrees in the essential points.

We find, in all cases in which the injury to the trunk and branches is so extensive, that the wood body composes part of the wound surface and that both the cambium lying between wood and bark which with undisturbed development makes possible the growth in thickness of the trunk as well as the young tissue elements directly formed from the cambium (which in the following will be included under the term "Cambium"), take over the healing of the wound surface of the mature part of the trunk. In herbaceous stems, or the still herbaceous developmental stages of woody trunks and branches other tissue forms can participate in healing the wounds as will be shown later in discussing individual cases under this head.

The structures of the forms developed from the cambium in the healing of wounds may, however, vary greatly from that of the normal wood ring. The reason for this difference in structure of *wound wood* should be sought in the fact that pressure conditions under which the tissue, serving for healing the wound, is produced, are very different from those existing during the formation of the normal wood body.

Supported by the investigations of G. Kraus, it should be recalled first of all that each trunk and branch has considerable internal tension, due to the difference in growth of its individual tissue forms which are connected with one another. The experiments on tissue tension begun by Hofmeister[1], extended by Sachs[2], and especially fully carried out by Kraus[3], have proved

[1] Hofmeister, Über die Beugung saftreicher Pflanzenteile durch Erschütterung. Ber. d. Kgl. Sächs. Ges. d. Wissensch. 1859, p. 194.

[2] Sachs, Experimentalphysiologie, p. 465-514.

[3] Kraus, Gregor, Die Gewebespannung des Stammes und ihre Folgen. Botan. Zeit. 1867, No. 14. ff.

that the growth in length of each branch of our trees is regulated by two factors.

The central tissue of the shoots, especially the pith, is the elongating factor[1], the tissue which forces the shoot into the air. Its very considerable striving to grow longer and to carry the surrounding tissue with it into the air which becomes evident in an isolation from other tissues is modified and retarded by the strain exercised by the very elastic peripheral tissue parts of the bark body. These contract and become shorter if isolated. They uniformly grow shorter even in their natural position on the tree in the night because of a radial swelling resulting from the taking up of water[2].

Therefore, as the shoot grows, there develops a considerable ***longitudinal tension*** due to the struggle of the elongating force of the surrounding tissues, at times of the bark body, to contract both themselves and those surrounding them. The result of this struggle is evidenced in the length of the pith cells within one internode. Cell measurements have shown that the pith cells are longer at first than they are later and that a very strong growth in breadth is associated with their subsequent shortening.

This increase in breadth is the result of the ultimate preponderance of the peripheral strain. When the increase in length of the internode is complete, the ***cross tension*** becomes great.

It is easy to understand that other strains must occur after the lengthening of a plant part is ended when one considers that the part of the trunk which has already elongated now thickens permanently and that this thickening depends upon the differentiation of the cambial cells, lying between the bark and wood, into new wood and bark elements of the following year; the year old shoot forms new wood layers above those of the previous year; these new wood layers must make room for themselves under the girdle formed by the bark and its outermost cork layers. This can be done only by a distension of the bark mantle which, however, does not give way without resistance. This resistance makes itself felt in pressure and thus, during the period of the growth in thickness of a shoot, we find the tender tissue of the cambium pressed on one side by the mature but still distending young wood and on the other side by the constricting influence of the bark mantle, which gives way only to very strong pressure.

Under this double pressure, the elements of the wood are formed from the cambium, that is, the elongated, thick-walled wood cells, poor in contents, or finally entirely empty, as well as the ducts and duct-like cells.

De Vries[3] has now determined experimentally that the cells of the wood become narrower (and the ducts fewer) the greater the bark pressure. He increased the constricting effect of the bark mantle by putting on a firm

1 According to Kraus (loc. cit., p. 141), Hales had already adopted the theory expressed by Borelli in his book "de motu animalium" that "The young shoot grows and elongates by the spread of the moisture in the spongy pith."

2 Kraus, G., Über die Verteilung und Bedeutung des Wassers bei Wachstums- und Spannungsvorgängen in der Pflanze. Bot. Zeit. 1877, p. 595.

3 Hugo de Vries, Über den Einfluss des Rindendruckes auf den anatomischen Bau de Holzes. Flora 1875, No. 7, Sanio, Bot. Zeit. 1863, p. 393.

band and in other specimens weakened artificiallly the pressure of the bark by cutting it longitudinally. He thus succeeded in explaining what Sachs[1] had already suspected, that the difference in the *production of the annual ring* is due to bark pressure, which changes regularly in the course of the year[2].

In the spring, at the time when the wood is most swollen because of its absorption of water, the bark pressure is very great, as may be noticed in the production at this time of new bark tears and the widening of those already present. During the unfolding of the foliage, the wood loses a great part of this water by evaporation. It then contracts, reducing the pressure of the distended bark. This explains the recognized formation of larger wood cells at this time. However, the more new wood is formed under the bark in the course of the summer, the greater will be its internal pressure against the underside of the bark; at the same time the bark layers lose a part of their elasticity because of drought and thus their resistance to the internal pressure of the wood becomes much greater. Under such increased pressure conditions, we find a production of narrow and broad celled, thick-walled autumn wood.

Another point, which I had an opportunity to observe in artificially constricted places, *is the increase of spiral twisting in wood elements due to the increased bark pressure.* Finally, in the overgrowing of constrictions made by wires, this twisting is found to be so increased that, in a certain zone of the overgrowth callus, the wood cells which otherwise have a longitudinal course lie almost horizontal. A radial section, made directly above the overgrown wire ring, shows a zone of wood cells cut across instead of lengthwise. These fibres, running horizontally, gradually reassume their vertical, normal course when the swelling becomes less and passes over into the normal trunk.

The increased twisting of the wood elements due to increased bark pressure explains also the well-known phenomenon of the non-parasitic, *twisted growth,* which occurs especially in dry, poor soils (with Syringa and Craetaegus) and has been observed in very different kinds of trees. The causes of the increase in bark pressure differ in the different cases.

The regular stratification in the wood body of the wide *spring wood* and *narrow autumn wood* thus caused is only a special case of the law proved by De Vries, that an increase of the bark pressure produces narrow celled wood but a loosening of the bark, on the contrary, a wide celled wood.

It is easy to convince oneself, however, by counting the cells after an artificial loosening of the bark, that this acts not only on the development but

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1 Sachs, Lehrb. d. Bot. 1st Edition, p. 409.

2 Investigations by Krabbe, published later (Sitzungsbericht d. Akad. d. Wissensch, z. Berlin, 14. Dez. 1882; cit. Bot. Zeit. 1883, p. 399) on the relations of bark tension to the formation of the annual rings and displacement of the medullary rays led to the conclusion that no effect on the annual ring formation could be ascribed to the radial bark pressure, on account of its insignificance. To me, the method used does not seem free from criticism, so that some doubt of the correctness of the result is justifiable.

also on the number of the cambial cells. *The less the bark pressure, the greater is the number of cell divisions in the direction of the radius of the trunk; the greater also the elongation of the individual cells and ducts in a radial and tangential direction, the lesser, however, in a longitudinal direction.* This change in the dimensions increases to such an extent that in those places where the bark pressure is almost entirely removed the thick-walled, elongated wood cells are found to pass over into short parenchymatous cells. In this, the differentiation of the tissue into cells and ducts is lost. Only a *uniform parenchyma wood develops.*

A work by Gehmacher[1] takes up the influence of bark pressure on the structure of the bark itself. His investigations lead to the conclusion that the greater the pressure, the fewer the cork cells formed and, conversely in the same way, the radial diameters of the individual cells differ. The cells of the primary bark parenchyma seem contracted not only radially but also laterally. Their form is, therefore, angular while in those produced under less pressure it is spherical with considerably larger intercellular spaces (which can disappear entirely under strong pressure). The number of bast fibres is said to increase considerably with a reduction of pressure (which I have not observed myself) and to decrease almost to disappearance with an increase of the bark pressure.

Nördlinger[2] also considers the production of a wavy periphery of the wood body, instead of the regular spherical one, to result from bark pressure. Where the wood seems indented the bark frequently appears thicker. The strongly developed groups of stone cells are said to be the ones which are pressed by the bark into the cambium and arrest the growth of the opposite part of the wood.

If we now give credence to the circumstance to which Kraus[3] calls attention, that part of the cell content is more quickly pressed out from the cell tissue under increased bark pressure, possibly toward those places in which the bark pressure is less, it can be no surprise that *a large amount of reserve substances are found stored* in the porous parenchyma wood, formed from the cambium as a result of the reduced bark pressure. The wide-lumined, thin-walled parenchyma wood is the most accessible center of deposition for the constructive material flowing toward it. For this reason, we see that where the wood cylinder forms parenchyma tissue instead of prosenchymatous elements, this usually (with the exception of the young callus rolls) is richly filled with reserve substances for a large part of the year and, in fact, in our trees also containing starch.

All the wounds to the tree trunk bring about a loosening of the bark. Nevertheless, the wood, formed in healing the wound, must vary in structure so much the more from normal wood and take on and retain so much the

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1 Aus Sitzungsber. d. Wiener Akad. d. Wissensch. Vol. LXXXVIII, pt. I; cit. in Botan. Centralbl. 1883, No. 47, p. 228.

2 Nördlinger, Wirkung des Rindendruckes. Centralbl. f. d. gesamte Forstwesen. Wien. October issue, 1880, p. 407.

3 Loc. cit., p. 138.

more the characteristics of parenchyma wood, the less the pressure of the bark girdle on the cambium at the time of ringing and the longer this loosening lasts.

We have seen in canker wounds how this porous structure at the edge of the wound causes more and more a new loosening of the bark, a new excrescent production of porous tissue and the final exhaustion of the branch, due to this production.

Every overgrowth edge formed about open wounds on the trunk, therefore, begins with the formation of short-celled, wide-lumined wood elements which, sharply bounded, lie against the normally exposed wood. The wood elements also pass gradually over into a normal structure, according to the increase of the overgrowth edges and, therefore, the stronger bark pressure. If, finally, the overgrowth edges coalesce and the bark again becomes a uniformly connected girdle around the trunk, or branch, the ***normal amount of bark pressure*** again sets in and with it the normal direction of wood cells and ducts. Every year normal wood is deposited above the closed wound.

Scarification Wounds.

The best example of the changes in tissues during the process of wound healing is found in the cicatrization of scarification wounds. By the term "scarification," as is well known, is understood the cutting through the bark, lengthwise of the stem, down to the wood body, without the removal of any substance. If the tree is slit in this way, the edges of the wounds pull apart (Fig. 173). Naturally, the two edges of the wound are nearer at the end of the incision (Fig. 173 *a*). The process of healing is completed most rapidly there. Fig. 174 shows the cross section of a healed incision on a sweet cherry tree, from the end of the wound, i. e. from the region marked *a*. We see at *h* the old wood, which was cut at *w*, and shows that part of its ducts and wood cells died because of the effect of the air. The cambial zone (*c*) which at the time the incision was made lay above *h* has formed, during the process of healing, new bark (*nr*) and new wood (*nh*). The newly formed wood zone, however, does not resemble the normal wood produced beneath the uninjured bark either in position, or in structure.

It forms one part which, projecting outwardly, is three-cornered in shape, its highest point coming nearest the groove (*s*) formed by the previous incision. This three-cornered convexity is caused by the development of parenchyma wood (*hp*) which exceeds that of the tissue lying farther at the side. This production of wood was the first activity of the two edges of the cambium which were separated by the incision (*s*). Here the bark pressure was the weakest, the cell increase the greatest, but the elongation the least. Only after the new bark, formed from the young, inner bark and the cambial zone, has attained at *s* a greater power and greater resistance because of the newly produced cork layer (*k'*) does the bark pressure gradually increase. Its influence on the cambial zone producing the wood is stronger and the form of the wood elements gradually becomes more like the

normal. The part *hp* passes over gradually into the regular wood much more distinctly divided by medullary rays (*m*). The transformation of the bark elements, taking place parallel to the change of the wood elements, will be described more in detail in the callus rolls due to girdling.

When the trunk grows further, the cambial zone (*c*) always deposits new normal wood and new bark with hard bast (*hb*) above the wound surface and when finally the old parts of the bark (*ar*), separated by the previous incision, with their cork zone (*k*) and the dead wound edges of the bark formation (*t*) which have been separated by the cork zone of living tissue, die and scale off, the wounded place externally becomes smooth and even.

We will have to consider Fig. 175, if we wish to go somewhat more in detail into the beginnings of the process of healing. This represents a cross-section through a single wound edge of a place of scarification (Fig. 173 *b*)

Fig. 173. Scarification wound. Fig. 174. Healed scarification wound.

in the sweet cherry at a time when this edge had not yet united with the opposite one, growing from the other side of the wound. The wound surface (Fig. 175 *w*) has not yet been covered. *h* indicates here also the old wood which at *w* has been exposed by the incision. At the time the incision was made, the knife passed from *s* to *w*. The old bark (*ar*) was drawn back towards the sides from this plane of incision. This part corresponds to that similarly indicated in Fig. 174. The upper part of this old piece of the bark, as well as the edge, which has dried out because of the incision (Fig. 174 *t*), is indicated in Fig. 175 by the contours marked *t* and only one hard bast bundle (*hb*) has been sketched in the bark parenchyma (*ar*). At the time the incision was made, the cambial zones (*c*) and the young inner bark (*ir*) lay close to the old wood (*h*). The cells which bounded the plane of the wound incision (*s* to *w*) reacted differently to the wound stimulus. The parenchyma of the older bark dried backward, for a certain distance,

and formed the brown, dry edge of the wound, recognizable to the naked eye, and thus enclosed each slit (Fig. 173 *c*). The parenchyma of the inner bark (*ir*), still capable of increasing, its growth not yet having ended, takes advantage at the edge of the wound of the opportunity of spreading toward each side where the pressure has decreased, that is, over the plane *s* to *w*. These cells, therefore, curve outward. Those from the cambial zone shove the first bark cells further out and mature, in the subsequently growing zone, to bark cells (*r′*) containing chlorophyll; and in this way the tender parenchymatous edge of the wound (*r′*, *ir*) is primarily produced. The peripheral cells (*r*) of the convex edge of the wound turn brown later and dry up.

Fig. 175. Overgrowth edge produced in a scarification wound.

Cork (*k*) is produced in the cells lying directly underneath this. This cork zone (*k* to *k*), covering the whole wall of the wound, now attaches itself to the outer cork covering of the old bark so that the new structure is surrounded by a very inelastic cork layer which consequently presses on the swelling tissue lying beneath it.

On this account, the bark pressure is also produced at intervals. The influence of this bark pressure on the immediately succeeding products of the cambial zone (*c*), which is bent forward like a snail but does not reach to the old wood (*h*), manifests itself by the formation of thicker walled elements. New wood (*nh*) is produced which toward the wounded side is

parenchymatous, short, with wide lumina (x) and perforated by isolated, short, wide ducts (g). The further the new wood lies from the edge of the wound, the more regular, narrow, dense and longer celled it is, the sharper appear the medullary rays (m) and their continuation (m') in the bark. The more gradual the formation of the new wood, the more taut is the tension in the outer cork zone (k to k) of the overgrowth edge. This frequently tears apart in places as a result of the inner pressure, so that the bark parenchyma is exposed and pushes out into the torn place. On these outpushing cells, new cork cells are formed in the shortest possible time, which lie against the surrounding ones and thus close the cork girdle.

Fig. 176. Cross-section through a hollow pine trunk in which only the circumvallation edges, several years old, carry on the nutrition of the trunk.

In case a scarifying incision is so broad that the overgrowth edge of the first year cannot cover it, the new wood of the following year will overgrow the wound surface like a lip. In this lip-like, convex overgrowth, which is recognized best by the course of the new covering cork zone (k to k, Fig. 175) the cambial zone (c) assumes a special curvature, which becomes more marked the deeper the wound surface lies. If it now happens that, in old trunks, a broad longitudinal wound is made, instead of a scarifying one, and the wound body is destroyed by atmospheric influences, together with parasitic action, so that the trunk becomes hollow, ultimately only the overgrowth edges will remain. Fig. 176 represents such a case. It is a cross-section from a hollow pine trunk[1]. Because of the slow rotting away of the

[1] The original may be found in the Botanical Museum in Berlin.

younger annual rings, the overgrowth edges have assumed a beautiful, spiral form, rarely to be observed, and the nutrition of the trunk depends on the comparatively slender wood layers of the last few years. The process is shown in less striking form in all hollow trees, for example, often in willows and poplars. In conifers, the rotting away of the trunk, as a result of longitudinal wounds, is a less frequent case, because the wound surface usually coats over with resin, or at least the parts of the wood exposed become resinous. This self protection, after a longitudinal injury, becomes most apparent in the gathering of resin, as Fig. 177 shows.

Fig. 177. Section of a trunk of **Picea vulgaris** with the overgrowth of the resin channels. The entire age of the tree is 70 years. The first resin tapping (a) took place at the age of 50 years, the second (b) at 51, the third (c) at 62, and the fourth (d) at 65 years. (After Döbner-Nobbe.)

The *wounds resulting from the gathering of resin,* in the form of strips some centimeters broad and about 2 m. long, from which the bark has been removed, do not die for some time. In spruce trees, R. Hartig found that the turpentine flowed in drops from the resin canals, lying in the medullary rays, soon after injury. Although a large amount of resin is accessible to the wound, since the resin canals running vertically in the trunk are in open connection with those of the medullary rays, yet the very fluid turpentine, as a rule, ceases to flow after the first year. The turpentine becomes thicker by the volatilization of the turpentine oil and the turning to resin (oxida-

tion). After the resin has been scraped off from both sides of the tapped place, the overgrowth roll is cut away in order to open new resin canals, or new strips of bark are removed from other sides of the tree.

Inscriptions.

Inscriptions and numerals cut into the trunks of trees, as also the irregularly gnawed and bitten places produced by the gnawing of wild animals in winter, should be mentioned as special cases of a common form of longitudinal wound extending into the old wood and connected with a loss of substance.

In inscriptions, the knife has removed considerable amounts of old wood and, therefore, has penetrated deeper into the trunk; on the other hand, however, the wound is not so broad. The healing of deep incisions begins at the longitudinal edges of the wound; the upper and lower edges share only to a very insignificant amount in this. The edges of the wound, produced by the cambial zone and provided with their own bark, extend further every year, forming overlapping layers, and thus gradually grow over the wound surface without becoming re-united with the old wood, of which the outermost cell layers, bounding the wound, turn brown and die. These healing layers form only a mass lying close against this wood, like the metal in a mould. At the moment when the two opposite edges of the wound of each letter coalesce, i. e. their cambial zones unite, these zones again form normally arranged wood elements, which become increasingly thicker because of the annual zone of increased growth, and thereby leave the original incision deeper and deeper in the trunk. In splitting the wood, a lucky blow will separate the intermediate layers, which had not been injured, between the individual letters or numerals, and the original brown mould falls away from the in-grown wood mass.

Injury Due to Wild Animals.

In injury due to wild animals, the wounds are broader, more irregular but, as a rule, extend only into the sap wood.

If the bark and sapwood are torn off from the entire circumference of the trunk, it dries up after a number of years, if the injury did not occur early in spring or in summer. As a rule, however, the gnawing and barking, due to wild animals, takes place only on scattered parts of the trunk and then there follows gradually a formation of overgrowths from the edges of the remaining bark. If such overgrowth edges are injured again in some subsequent year, before the first wound is closed, the wood body apparently takes on a very complicated formation of annual rings.

The injuries differ with the kind of animal. According to Ratzeburg[1], red deer and elk, but not the roebuck, "peel" the tree, since usually in the spring, in feeding, they loosen strips of bark at the bottom by means of their incisors and then tear them off upward. The healing then takes place either

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[1] Waldverderbnis, I, p. 50 ff.

by overgrowth or, in some cases, by a new formation of bark (cf. Barking of Fruit Trees). The bark may also be worn off by rubbing and blows, but in this the half-loosened remnants remain on the edges of the uninjured bark in the form of tatters, or small rapidly drying and, therefore, curling strips. Usually the traces of hair on the bark remain. Since deer and roebuck rub their horns up and down against the tree, to free them from the velvet, these *rubbing wounds* are longer than the peeling wounds and more frequently extend around the trunk. Now, the roebuck sheds its velvet in February and March; the deer about the first of May, and others four weeks later. The wounds, due to the latter, therefore, fall in a time when the tree has the greatest amount of plastic material at its disposal. They will, therefore, heal much more quickly than wounds made in the winter and spring. It thus happens that the wound does not once reach the cambium, but only removes the outermost bark layers. If the inner bark remains in place the annual ring develops almost normally beneath it from the cambium, at least, so far as the arrangement of wood and vascular elements is concerned. The wood cells, however, are usually thinner walled, with broader lumina, the ducts much more numerous, the whole annual ring broader. If the weather is wet, or the habitat of the trees shady and damp, a callus tissue frequently develops on the outerside, from the cells of the youngest bark which has been left in place. This callus tissue leads to the formation of new bark; in rarer cases, with luxuriantly growing trees, to the formation of isolated wood bodies.

Wounds from blows and splitting of the bark also arise at the time of "rubbing" and in the period of "heat" in the late summer. A different method of healing the wounds now often sets in, since a callus tissue is formed from the youngest sapwood layers on the wood body, which has been freed from the bark; it fills out the hole, as in budded trunks (cf. Budding).

We have still to consider *gnawed wounds,* as produced by mice and rabbits, beavers and hares. The latter, with their teeth, cut young branches or weak plants. Real gnawing, which is so disastrous for our fruit trees, is found usually only after deep snows. The wounds extend to the older wood on which may be recognized the tooth marks. If these reach around the trunk in connected surfaces, the tree is lost. If, on the other hand, isolated particles of bark are left in place, an overgrowth takes place from these.

According to v. Berg, it is advisable to fell Aspens and Sallows (*Salix caprea*), which game peels, at once, in order to protect the other trees from similar injury. Finally, the scattering of food, during the winter, might be cited as the best means of protection. We insert this chapter on the injury due to game only in its relation to the anatomical processes of healing wounds. This subject is treated very thoroughly in a recent work by Eckstein[1].

[1] Eckstein, Die Technik des Forstschutzes gegen Tiere. Berlin 1904, Paul Parey.

In places where grazing cattle are driven into the forest they frequently cause greater injury than do game. Roots will be exposed to such an extent that whole trees die along the paths. Sheep and goats bark larches, firs and balsams, etc. As v. Mohl indicates, and Ratzeburg confirms, deciduous trees endure injuries to their trunks, extending to the cambium, much better than do conifers.

Klein, in his latest forest-botanical note book[1] gives numerous and good reproductions of trees that have been gnawed by grazing animals.

Overgrowth of Cross Wounds in Many-year Old Trees.

If branches, or trunks, are cut across the same processes of breaking the bark and the new formation of overgrowth edges must set in as were

Fig. 178. Remains of a sawed off branch which had died back from the cut surface and which had been covered over as with a cap, by the overgrowth edges of following years.

described above in scarification. The injury, however, in itself is much more dangerous because in this all the annual rings of the branch are exposed and the effect of the atmosphere and wood destroying fungi is uncommonly facilitated.

We see in the adjoining cut (Fig. 178) the product of several years' overgrowth of the old stump of a branch. The darker, central part is the cut end of the branch, which, under the influence of the atmosphere, has died far back into the trunk. In five years, the wood cap of the overgrowths

[1] Klein, Ludwig, Bemerkenswerte Bäume im Grossherzogtum Baden. 214 Illus. Heidelberg 1908, Winters Universitätsbuchhandlung.

which have extended farther each year, has been formed over the surface of the wound and has finally closed it. The overgrowth in this case has taken place principally from above, since most of the plastic material has come from that direction. In a slender, longitudinal wound the overgrowth takes place principally from the sides.

The process of overgrowth, which sets in in the branches of trees, also causes the closing of wounds on cut or chopped surfaces of stumps left when trees are felled. The process extends only comparatively slowly, since the cambial ring producing the overgrowth edges has to cover a very large wound surface. The result is that, long before the overgrowth edge has reached the central part of the cut surface, this has decayed and the center of the branch in consequence has become hollow. The overgrowth masses now sink down into the cavity in very different forms and, at times, in twisted cords covering projecting splinters or stones. Thus they can attain a considerable size[1].

The question is now pertinent, whence comes the material necessary for such an extensive new formation. The opinion usually expressed is that the reserve substances, formed before the felling of the tree and present in the stump, can be the only source of all the new structures. In other cases, root union, which occurs not infrequently, is used to explain this, for it is assumed that the stump is nourished by the uniting of its root branches with the stronger roots of adjacent trees, which still retain their crowns.

Certainly, cases of this kind are not rare in larger tracts of trees[2] and such a nourishing trunk can actually give considerable assistance to the stump. Nevertheless, there also exist instances in which absolutely isolated trees have formed such large overgrowth masses on the stump that the supposition of a production of such massive new structures from the reserve substances alone does not seem sufficient explanation.

In my opinion, however, there exists universally in such cases an accessory apparatus, which is capable of conveying newly assimilated material. If the young overgrowth edges are investigated more or less chlorophyll will be found in their bark, according to the amount of light the trees receive, and it is by no means clear, why this chlorophyll apparatus should not assimilate just as well as the green bark of the trunk. The fact that branches are found growing out of older overgrowth edges shows how abundant is the life prevailing in them[3].

The formation of branches from the cambial ring of tree stumps is a very common occurrence, which comes to view on all sides with felled poplars and arises from the production of adventitious buds in the parenchymatous overgrowth tissues.

[1] Good illustrations of such cases in Göppert, Nachträge zur der Schrift über Inschriften und Zeichen in lebenden Bäumen. Breslau, Morgenstern 1870.

[2] Göppert, Beobachtungen über das sogen. Überwallen der Tannenstöcke. Bonn, Henry & Cohen, 1842.

[3] v. Thielau, in Lampersdorff near Frankenstein in his advertisements of the Göppert Treatise (Über die Folgen äusserer Verletzungen der Bäume, etc.) in May, 1874.

Even in the poplars a complete circle of strong green branches grows up around the edge of the cut wood body. Such an *"eruption of shoots"* degenerates, as a rule, after a few years because it is not able in its place of production between bark and wood to form new roots which can reach the soil. If soil reaches the base of these shoots by being covered or by premature decay of parts of the bark, the shoots can free themselves from the nutritive trunk by growing roots and form long lived, independent individuals.

The ability to produce new shoots from the tree stump, very differently developed in different tree genera and very rarely in conifers, does not always depend on the formation of adventitious buds but also on the awakening of dormant eyes as in conifers. In this, however, the hard cortex of the stump often hinders further development.

If such a subsequent development of shoots is expected and desired, as in forestration or in parks, the trees *must be cut down as deep as possible* in order to give the new shoots a good chance to root.

The custom, not infrequently found, of renewing tree plantations by leaving stumps one meter high, should be given up absolutely. The new shoots developing on such stumps are, on an average, much weaker and are often surpassed by shoots at the surface of the soil.

Overgrowth Processes in Year Old Branches.

In our cultivated trees, the necessity arises of cutting back the tops in order to prune the foliage shoots and thus favor the fruit buds, or in transplanting to bring the top into balance with the injured root system. The pruning affects principally the year old growth, and is done either in the fall or early spring. Consequently, a considerable time passes before the processes of closing the wounds begin through new formation of tissue. In this it is found not infrequently that such young growth dies back for a short distance from the cut surface.

In Fig. 179 is shown the tip of a year old cherry branch which has dried back some distance from the cut surface. Fig. 180 shows the same branch cut through longitudinally; *s* to *s'* is the original cut surface; *t* is the boundary layer, back to which the twig has died; *a*, a swelling frequently found in such cases. Fig. 181 shows the anatomical structure. In it, *s* to *s'* is the plane of the cut, *a h*, the last peripheral particle of the old wood of the cut surface; *a r*, the old bark with its outer normal cork layers (*k*). Of this bark, the tissue indicated by *T* has dried back and, in fact, the tissue near the hard bast cords (*b*) dies the furthest downward; the bast cord is also dead and together with the outer cork layers of the bark, which also are but little shriveled, projects from the discolored parenchyma. The cut surface is, therefore, uneven and rough.

The next process which sets in, after injury and after the upper bark tissue has died, consists in the cutting off of the dead from the healthy tissue, by means of the formation of a cork zone (*k'*, *k"*). The cork zone is devel-

oped more extensively about the base of the bast bundle and represents a radiating overgrowth (k''). The increase in cell numbers begins at once in the layers of the cambial zone (c) lying next to the cut surface, and of the bounding, inner bark which, at the time the pruning was done, lay close to the wood body ($a\ h$).

Exactly as in the protuberance of the roll in the scar wound shown in Fig. 173, the protruding bark zone ($n\ r$) is formed from the products of the

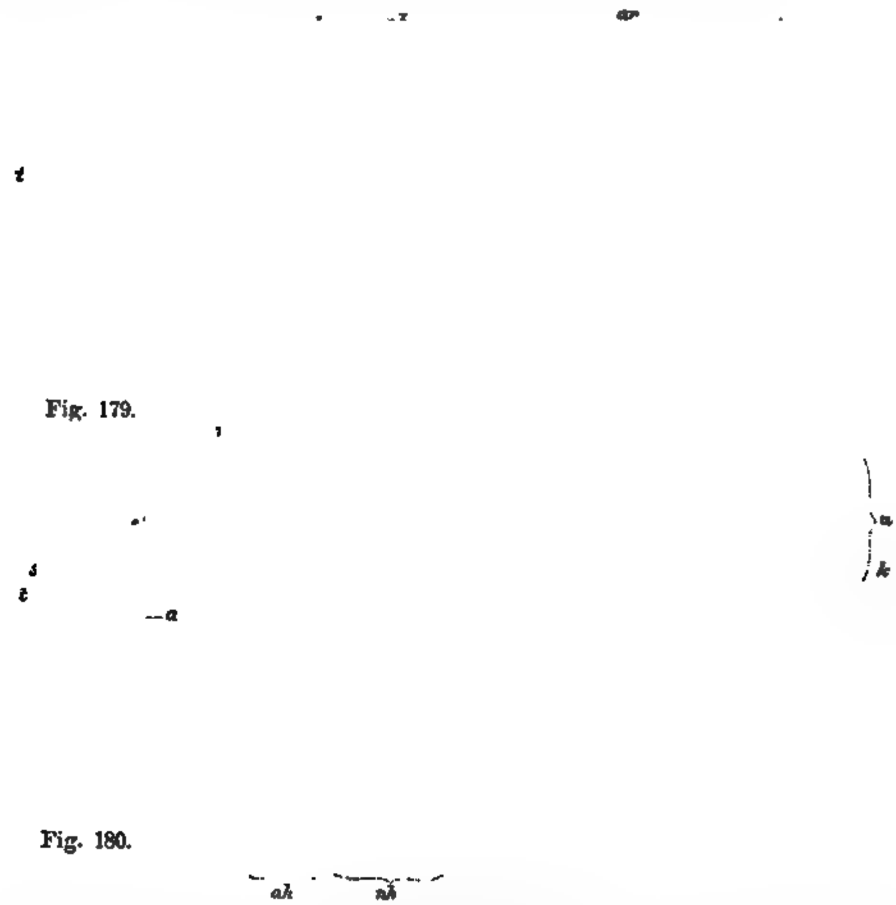

Fig. 179.

Fig. 180.

A one year old branch of the sweet cherry cut through in cross-section, the cut surface of which has dried back.

Fig 179. From without the cut surface of the branch appears somewhat dried back and has a swelling (a) below the dried tissue Fig. 180. The same branch cut through in the median line Fig. 181. Anatomical sketch of the region a to r of Fig. 180.

cambial zone and the young bark, and this protuberance is closed in the same way by a cork girdle ($k'\ k'''$). The wood products of the cambial zone, the maturing of which changes gradually because of the pressure of the newly produced wound bark, are produced at first as parenchyma wood (hp) in which cord-like, short, porous duct cells (g) occur. The further the formation of the new wood, produced after injury, is traced back from the cut

surface, the more the elements of this wood are found to resemble the normally elongated, thick-walled elements (*g'*, *h'*). In the drawing, the transition from the short vascular elements to the long ones is interrupted by the continuation of an old medullary ray (*m*) into the medullary ray (*m'*) of the new wood.

Besides this formation of new wood and independent of it still another cell increase manifests itself in the bark near the hard bast bundle. The parenchyma cells divide and increase, thereby, the thickening of the original bark, which is forced out by these new growths and causes the externally visible swelling (Figs. 179 *a*, 180 *a*, 181 *a*). Under certain circumstances, the new growth within the bark is so intensive that a meristematic zone is produced, which remains active for some time, producing in turn wood and vascular elements, and gives rise to the formation of wood fibres in the bark, said to have been found in the production of gnarl tubers.

The drawing of a cut branch, reproduced in Fig. 181, does not agree entirely with the structure found in the overgrowing cross-wound of the stump of a branch. The reason for this is that we usually think of such cuts as having been made late in the spring or summer on older branches. In these cases the drying back of the tissue from the surface of the wound is not extensive until the time when the wound begins to heal, i. e. until the formation of the overgrowth edge (*nr*, *nh*). This overgrowth edge soon appears above the cut surface and lies in a curve over the old wood, which had been formed before the time of pruning and is indicated by *ah*. The arrangement of the elements then corresponds to the formation of the callus roll in the cuttings illustrated in a later figure; the nature of the cell elements remains that shown in Fig. 181.

As the branch becomes older and the wood layers, formed from cambial zones, become increasingly thicker, the overgrowth edge, projecting on all sides above the cut surface of the branch, also becomes thicker and thicker until the opposite sides touch one another and unite in a cap which entirely encloses the cut surface.

Each overgrowth edge begins in the way shown in cross section in Fig. 175. It can, therefore, be said, *figuratively,* that the new wood layers, formed after injury, spread over the old wood body, laid bare by pruning, and finally shut it in by a cap.

Girdling Callus.

By *"girdling"* is understood the removal of a small circular strip of bark around the whole axis, usually at the time of the greatest cambial activity, since only at this time can the bark body be loosened easily and completely from the wood.

In girdling, only the part of the branch lying above the wound receives the plastic material prepared by its leaf apparatus. This cannot, as destined, be used to strengthen the wood ring for the whole length of the branch, but is held back above the place of girdling, thus conditioning a

more abundant cell increase in the cambial ring at that place. We find that the diameter of the upper part of the branch has strikingly increased in proportion to that lying below the girdling cut. The supply of water carried up from the roots to this place is at first, however, considerably decreased. In the first place, the amount of water ascending in the bark is prevented from rising further by the girdling cut, and then the main stream, ascending in the wood, loses no inconsiderable amount of water at first by evaporation at the place laid bare by the girdling. Therefore, in the upper part of the branch the main factor of cell elongation, turgor, is decreased by the lessening supply of water from below. The cell increase is indeed greater but the cell elongation is less than in the normal branch. While the growth in thickness of the part of the axis, which lies above the girdle, is increased, the apical growth of the branch remains moderate; the internodes are not as much lengthened. Shortening of the internodes with abundant supply of plastic material is the first step toward the formation of fruiting wood; thus *fertility of the branch is more rapidly brought about by girdling.* The part of the branch above the girdling is demonstrably poorer in water; its leaves, likewise poorer in water, take on an autumnal coloration earlier, and the ripening of its fruit is hastened.

The assertion that larger fruit can also be obtained by girdling has been confirmed only in certain cases. Grapevines, for example, and the American varieties especially, after girdling seem still to get such a considerable amount of water in the upper part of the vine that no retarding of the apical growth is noticeable. In this case, therefore, the development of the fruit depends essentially on the amount of plastic material and this varies in different years, according to the prevailing atmospheric conditions. In the same way, the character of the variety is of influence. For example, Paddock[1] observed that the variety of grape, "Empire State," ripened its fruit three weeks earlier than usual because of girdling, the "Delaware," on the other hand, showed scarcely any reaction and, in fact, its quality was poorer.

Girdling is used on grapevines as a means for curing the dropping of the young berries[2], but as a constant regular treatment in cultural pruning girdling will never find an opening; it may always be used only as a drastic, exceptional method, in special cases, the injuriousness of which frequently exceeds its usefulness.

Even in the grapevine, in which girdling is used most frequently, its use must remain limited. In the "Annalen der Oenologie"[3] Göthe judges that the hope of a general application of the process in grape culture will not be realized. The advantage of hastened ripening, he thinks, is unmistakable. In this way, late varieties may still be brought to ripening, but the grapes of girdled vines give a worthless wine. The part of the vine

[1] Paddock, W., Experiments in Ringing Grape Vines. New York Agric. Exp. Sta. Bull. No. 151, 1898.
[2] Jäger, Obstbau 1856, p. 125.
[3] Vol. VI, 1877, Part 1, p. 126.

above the girdled place dies (at least in European varieties), the part below it is poorly nourished, so that the eyes remain sterile and should not be taken into account in pruning. Besides this, girdled shoots break off very easily.

In many trees also there is found frequently a hastening of the development of the leaf buds below the place girdled, which can increase to the formation of water sprouts. This case is more frequent in apple trees than in pears.

Recently, girdling has also been made use of in herbaceous plants with edible fruits. Thus, for example, Daniel[1] obtained larger fruit with the Solaneae by this treatment. Other observers could not confirm this, but found a retrogression in the development of the whole plant[2].

If we now pass over to the study of the anatomical conditions produced by the girdling cut, or "*pomological magic ring*," by means of the adjoining illustrations, we shall, we believe, best further thereby an understanding of the matter by giving first of all a general description of Figs. 182 and 183.

Fig. 182 represents a girdled grapevine; *u* is the lower overgrowth edge, *u'* the upper edge; *bl*, the bared surface of the wood body.

Fig. 183 is a longitudinal section through the lower, smaller overgrowth edge (Fig. 182, *u*). *S,S'* is the plane of the lower knife cut in girdling; *S,S'C'* is the protruding tissue of the overgrowth edge. *H* represents the outermost layer of the exposed wood body; in this, *g,g'* indicates the ducts and *h,h'* the porous wood cells. *R*, as in Fig. 182, is the bark cut through in girdling, which appears pushed back from the wood by the outswelling overgrowth tissue (*r,C,C'*). This tissue at *s'* lies close against the wood and is protected externally by a cork layer (*k,k'*). This protruding overgrowth edge of parenchymatous tissue is differentiated by the arched cambial zone *c,c,c'*, into the parenchymatous wound wood (*wh*) and the wound bark (*wr*). Both are traversed by radiating medullary rays (*m*).

Fig. 182. A ring-ing wound on a grapevine with the upper, more strongly developed overgrowth edge (u') and the more weakly formed lower one (u).

Figs. 184 and 185 show how such an overgrowth edge appears in cross section. The first was taken from the upper wound wall, close to the place where it leaves the bark; the second figure originates from a broader, most distant region.

In considering Fig. 183, we see that a mass of tissue has protruded from the edge of the wound produced by a 3 to 4 fold division of the

[1] Daniel, Lucien, Effets de la decortication annulaire chez quelques plantes herbacées. Compt. rend. Paris 1900, p. 1253.
[2] Hedrick, Taylor and Wellington, Ringing herbaceous plants. New York State Agric. Exp. Sta., Geneva, Bull. No. 288. 1906.

cambium and having at first the character of *callus*[1]. This holds good for the products of division of the youngest bark, which united with the cambial callus from the later overgrowth roll.

At the time of girdling (in July) the old wood body of the vine (Fig. 183, *H*) was already strongly developed. We can recognize elongated, thick-walled wood cells in the immediate proximity of the ducts (g), chiefly

Fig. 183. Longitudinal section through an overgrowth roll which has developed from the lower edge of the ringing wound (Fig. 182, u).

provided with horizontal cross walls (h), otherwise usually pointed like a wedge and having fine pore canals (h'). The narrower vessels are spiral or ring ducts (g); the wider ones show circular or slit-like pits (g'). The broadest of all have a ladder-like, or reticulated, porous wall. The ladder-

[1] All juvenile cicatrization membrane with apical growth of its cell rows, no matter whether produced on a cut surface above or beneath the surface of the soil, may be called "callus." We will call the callus which has a bark, is lignified, and continues its growth by an inner meristem zone the "overgrowth edge."

like arrangements of pits corresponds to the pores of the cells surrounding the ducts in rows, the walls of which cells are pressed against those of the ducts.

The lower cut, by which the ringed place was laid bare (Fig. 182 *bl*) is indicated in Fig. 183 by the plane *S,S'*. In this longitudinal cut, therefore, the girdled exposed surface extends from *S* upward along the exposed wood cells. At *S'*, we see how the knife has smoothly cut the bark (*R*) perpendicular to the longitudinal diameter of the vine. At the time the cut was made, the bark (*R*) lay close against the wood (*H*). The tissue lying between them and projecting far out (*r,C,C'*) has been produced after the girdling. And, indeed, the extreme lessening of the bark pressure connected with the removal of the bark in the sectional plane *S,S'* and the parts adjoining it in the cells of the cambium, as well as in those of the youngest wood, likewise in those of the younger and youngest bark, causes a formation of callus with a surprisingly great cell increase, since the end cells of the tissues named and those directly adjoining them push outward, divide, elongate and cut off their anterior ends by cross walls. In these anterior ends, the elongation and construction is repeated many times. In this way, a callus wall (*C,C'*) projects in a circle, around the cut edge of which the inner side at *z'* lies close against the wood, without uniting with it.

At any rate, this callus wall at first has neither the extent nor the structure given it in the drawing; this represents rather a wound wall developing from the callus which, by the increase of the new cambial zone (*c'*), has already formed secondary elements of thickening. Originally this callus wall consisted only of thin-walled parenchymatous cells (*z,z'*) appearing immediately and radially arranged, their diameter in all directions being almost equally long.

In such a juvenile callus wall, which is early differentiated, a cork zone is formed (*k,k'''*) first of all on the outer circumference. It gradually increases in thickness and serves as a layer protecting the thin-walled, newly formed tissue mass. The cut surface of the old bark tissue (*R*) which has been separated widely from the wood by the new wound tissue, is cut off in the same way by the cork layer (*k''*). The old, hard bast cells (*b*), which have been cut, have turned brown from the cut surface deep down into the healthy tissue and died. The original bark tissue (*r*) lying inside and back of these bast cells has participated in the cell increase and callus formation; only the cells lying next to the hard bast of the original bark have formed a cork zone (*k'''*), cutting off the dead part. Near this cork zone run the hard bast cells (*b'*), which were already formed at the time of girdling, but under the influence of the cut do not extend normally as at *b*. The elements of these cells arranged in rows may be traced backward into the healthy tissue and gradually pass over into the old bast; this row of cells is continued in the wound wall in the elongated, but very thin-walled groups of cells (*b''*), which lie at equal distances from the cambial zone.

The cambial zone, which runs close to the prosenchymatous wood elements in that part of the normally developed vine which lies below the place of the cut, describes a wide circle *c,c,c'* at its entrance into the wound, or overgrowth wall; it divides the apparently uniform ground tissue into one part lying against the old wood body of parenchyma cells with strong, porous walls, the ***wound wood*** (*wh*), and an outer part, the ***wound bark*** (*wr*). In the clearly marked, radiating arrangement of the individual cell rows, this row is recognized as a secondary growth of the cambial zone, appearing very early in the callus roll. The elements formed from the cambial zone have approximately the same parenchymatous form in the same horizontal surface, only, as already said, the parenchymatous wood (*wh*) differs from the bark tissue by its porous walls, which are more greatly thickened and more dense and, therefore, lie against one another with sharper angles; a stronger pressure has already made itself felt here.

But an evident differentiation is noticeable in the bark tissue itself. Between the somewhat oval cells, forming the ground mass of the bark, we find more elongated, more slender, somewhat prismatic cells arranged in a curve (*b"*) approximately parallel to the cambial zones. These represent the very beginnings of the hard bast cells. They are richer in content and accompanied by pouch-like cells, which, in their longer axis, usually run parallel to the young bast bundles and contain raphides of calcium oxalate (*o*). The bark tissue produced from the youngest bark already formed at the time of cutting and containing thick-walled, but short and broad hard bast contains its calcium oxalate in the form of stellate druses, or separate crystals, similar to those which occur chiefly in the normal bark (*o'*). At the place of the transition, raphides and stellate druses are often separated from each other only by two cells. Here also only the loosely constructed tissue contains raphides.

The parallel arrangement of the crystal-containing cells, with the bast fibers, is seen best in tangential section in the cherry; here the base bundles, lying in a net work upon one another, are found to be accompanied by parenchymatous cells lying close against one another and elongated. Almost every one of these contains a crystal of calcium oxalate. In the grape this is less sharply marked and becomes relatively indistinct as the tissue, as a whole, loses its differentiation in the overgrowth walls. In this less differentiated part may already be recognized thicker walled elements lacking the deposition of calcium oxalate in the surrounding tissues. The calcium appears in the cells formerly filled with starch, a fact which indicates that the calcium oxalate is one of the end products in the solution of the carbohydrates.

Therefore, no calcium oxalate is found in the outermost peripheral zones of the overgrowth edge because these zones consist of the first formed tissue of the quickly growing undifferentiated callus projecting beyond the cut surface. In these the material has been utilized entirely for cell increase and is not deposited in the end as reserve starch. On the whole, however,

only a few peripheral cell rows always remain free from starch and free from subsequently formed calcium oxalate, for the tissue which extends beyond the cut surface, and which warrants the name "callus" only so long as it is absolutely undifferentiated, soon shows a difference in its structure and passes very rapidly from the callus stage into that of the overgrowth edge. Soon after the formation of the peripheral cork covering, a meristem zone appears also in the interior of the callus tissue and represents the continuation of the cambial ring of the normal piece of the vine within the overgrowth edge. Besides this meristematic zone, the first traces of a bast body may also be recognized in the separated parenchymatous cells lying scattered close under the cork zone. These cells appear to have somewhat more strongly refractive, easily swelling walls (*b″′*). In some of these I think I have recognized indications of sieve pores similar to those found in the tangential walls of normal bark sieve cells (*sz*), so that the conclusion may be drawn that the first differentiation of the callus tissue, appearing almost simultaneously with the formation of the new cambial zone, consists in the formation of sieve cells within the bark.

The tissue formed in the cambial zone appears, in Fig. 183, to be divided longitudinally by the medullary ray cells (*m*). These are elongated radially, have clearer contents and like the rest of the tissue are small celled at the periphery of the overgrowth edge. Their approximately perpendicular direction changes gradually into the normal horizontal one as the rays extend into the normal tissue of the uninjured piece of the vine.

In the youngest portion of the callus edges, where the tissue lying next the cork border first arose, one finds the wood lying between the clearer medullary rays to be short, thin-walled and parenchymatous. The further the wood is examined back toward the normal tissue, the longer and thicker walled it appears and it passes from its radial direction more and more into the longitudinal elongation of the normal wood elements. The earlier in the year the girdling is undertaken, i. e. the longer the newly produced cambial zone of the overgrowth wall produces wood, so much the more do the later formed elements approach normal wood in length and form.

Scalariform vessels (*g,z*) appear in this thin-walled parenchymatous wood as the first thick-walled elements; they have at first the size and arrangement of the wood parenchyma cells of the surrounding tissue but assume gradually the form and arrangement of normal vessels the nearer they approach the uninjured parts of the wood. In opposition to de Vries, I must maintain that the short duct cells are not always the first formed thick-walled elements. When the callus at the lower margin of a girdle is very weakly developed, the wood parenchyma often passes over directly into normally arranged, slightly thickened xylem elements, without the previous appearance of short duct cells.

In the callus at the upper margin of a girdle which in the same length of time has developed more than twice as extensively as the lower callus, the cambial zone is broader, all the elements are more numerous and the

beginnings of the vascular bundles in the callus always start with duct cells. The formation of these cells takes place the earlier the nearer to the old wood they are formed. Their form, size, thickness of wall and arrangement will be more nearly normal the further back the tissue lies from the cut surface. The vascular strand (g,z) of this tissue grades gradually into the normal wood formed before girdling, thereby forming a pseudo-secondary growth in that area.

According to the anatomical conditions shown in Fig. 183, we may say that the girdling has produced an unusual loosening of the wood in the uninjured part of the vine adjacent to the wound. In this way the vascular bundles, which are formed of vessels and thick-walled tracheids on one side of the cambium and of the thick-walled phloem fibres and sieve tubes on the other, and which, in normal wood, are arranged close against one another in concentric circles, are separated and broken up into single strands by masses of parenchyma. These strands, g,z (vascular strands), and b' (phloem strands), the elements of which constantly become fewer in number, change constantly and continue into the callus, which is gradually covering the girdle.

Fig. 184. Cross-section through a ringing roll close to the point where it appears on the plane S to S' in Fig. 183.

We may best see by means of cross sections taken at different heights through the callus, what happens to the vascular cylinder which in the uninjured portion of the vine consists of the wood and the phloem rings, only slightly broken by few-celled medullary rays. This cylinder finally is separated into single strands by the growth of parenchyma induced by the girdling. The strands gradually become narrower as they pass outward radially and tangentially in wavy lines, they are at first distinct, but later anastamose forming a net and finally split up into isolated strands arranged in fans.

For the sake of greater clearness, the cross sections shown in Figs. 184 and 185 have been taken from the upper similarly constructed but more

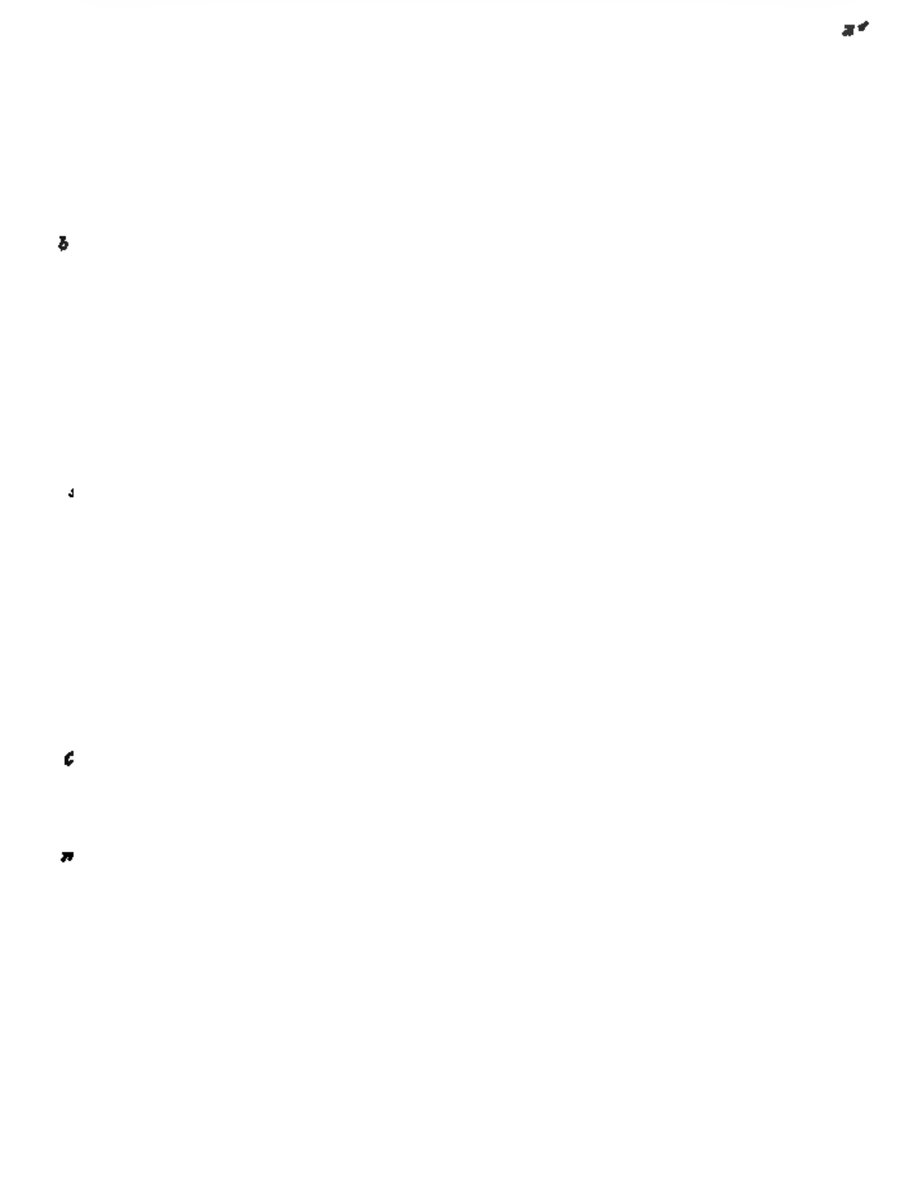

Fig. 185. Cross-section through the ringing roll at a considerable distance from the place of its appearance, i. e. where it is more luxuriously developed, as would be found in Fig. 183, possibly in the plane k to wh.

strongly developed callus of the same vine, which furnished the longitudinal section, Fig. 183.

Fig. 184 shows the callus in cross section at the place where it leaves the old bark, i. e. about at *S* to *S'* in Fig. 183. Fig. 185 is a cross section through the middle of the projecting part of the callus, i. e. about in the place *k* to *wh* in Fig. 183. In Fig. 184, *H* represents a part of the old wood formed before girdling. *g'* indicates the wide, scalariform vessels of which those lying nearest the cut surface *S* to *S'* have filled with tyloses (*t*) as a result of the injury, and consequently have become impervious to air; *h* shows the tracheids in cross section. *S'* to *C'* (in Fig. 185, *C* to *C'*) is the new wood formation of the callus. We find that the medullary rays (*m*), from the normal tissue (*H*), are continued, after a short interruption, into the callus. The medullary rays become constantly broader; the vascular bundles, the xylem elements of which in normal wood are closely packed, are separated further and further by the constantly widening medullary rays. The bundles thus have fewer elements and normal tracheids are no longer present. The strand (*st'*) consists only of short, wide vessels, and narrow ones with transverse walls, together with wide, thinner walled wood cells, abutting on each other transversely.

The single strand in Fig. 184 (*st*) in the normal wood has divided in the tissue of the callus into two strands (*st'*), and these again into four strands in the part still further from the cut surface (Fig. 185 *st'*), at the same time the new bundles are pushed out of their original position by the formation of new medullary rays (Fig. 185 *m'*). They advance as separate groups toward the periphery of the constantly thickening callus. With the broadening of the tertiary medullary rays these thin vascular strands (Fig. 185 *st'*), which (in longitudinal section) seem to branch as they growth in length, separate farther and farther from each other until they finally disappear entirely near the outer edge of the callus. The terminals of these strands are short, broad, porous cells of wood parenchyma.

It is well known that each vascular strand is made up of both phloem and xylem. The wood and phloem are sister elements[1] In Fig. 184 *b*, we see a group of wood fibres, which belongs to the xylem strand *st*; *b'* and *bb'* represent the phloem, belonging to *st'*, the cells of which, analogous to wood elements, have become broader. The radial thickening of the phloem cells is not very well shown in the drawing.

In the fall, when the grapevine has cut off the cortex by a cork zone, the sinuous cork layer (*k*), in the callus, has divided the phloem bundles into two parts (Fig. 184, *b'* to *bb'*); *c'c'* represents in Figs. 184 and 185, the cambial zone. In Fig. 185, *o* is a pouch cell with calcium oxalate in the form of raphides. In some pouch cells sharp, jagged very small protuberances project from the inner cell wall.

The first differentiation in the callus may still be recognized after it has passed over into the finished overgrowth of the callus, beginning at the outermost cork layer; i. e. if, in Fig. 185, the section begins at the part curling farthest downward and then advances upward. If we designate the part

[1] Ratzeburg, Waldverderbnis I, 70.

adjoining the old wood (Fig. 183, z' to S), as its innerside, in contrast to the spherically convex outer side, the parenchymatous tissue of the inner edge, lying directly under the cork zone, is seen even in the second sections to color more deeply when treated with iodine than does the corresponding part of the opposite outer side. In the same way, by using iodine, a radial division of the tissue may also be recognized, for certain bands at first only one to three cells broad take on a deeper color than the broader parts lying between them. A difference may be seen also in the form of the cells in the first cross sections, for those lying nearer the outer edges appear rounder than the more densely crowded ones nearer the inner edge; also all the cells, lying directly under the corky outer layer, are smaller than those at the centre. The lighter colored bands contain cells with a greater radial elongation, the first indication of the medullary rays. The zone of the renewed cell division, which will form the beginnings of the later cambial rings, lies close to the inner side of the callus roll adjoining the region of cells which were the last to divide to strengthen the peripheral cork zone. From there, in the subsequent cross sections, the division zone moves farther and farther from the old wood (compare the curved course in the longitudinal section, Fig. 183, c to c'), reaching its greatest distance from the old wood outside the plane in which the girdling occurred and again within the old bark, approaching the normal wood until it takes up the usual position of normal cambium.

The principles that have been discussed here in detail with reference to the grape are expressed in any kind of girdling, the special structure naturally varying with the kind of plant.

Czapek[1] has shown that, of the conducting elements, only sieve tubes and cambiform cells come under consideration for all assimilating products, indeed, the paths which convey substances are straight, even in the phloem. The phloem parenchyma, like the medullary rays, serves as storage tissue. The deposition of reserve substances is influenced by girdling, inasmuch as (according to Leclerc du Sablon[2]) the roots of trees girdled near the base of the trunk in the spring at the time of sprouting are richer, and the trunks poorer, in reserve materials, than those of trees which have not been girdled. The leaves of the former to be sure are not so green, but contain much more reserve materials than ungirdled specimens and according to my observations color much earlier in the autumn.

Injuries to the Bark.

A. Historical Survey.

The processes of healing a wound which has exposed the wood all the way around the trunk often a meter in width, produced by the removal of

[1] Czapek, Fr., Über die Leitungswege der organischen Baustoffe im Planzenkörper. Bot. Centralbl. 1897, Vol. 69, p. 318.

[2] Leclerc du Sablon, Recherches physiologiques sur les matiéres de reserves des arbres. Revue générale de Bot., Vol. XVIII; cit. Bot. Centralbl. v. Lotsy, 1906, No. 43, p. 447.

all tissue down to the cambium, have been the subject of observation for more than 100 years.

Thus Treviranus[1] quotes that L. Firsch found some apple and pear trees on an estate in the Province of Brandenburg, from which all the bark had been removed from the points of insertion of the lowest branches down to the roots, completely around the trunk, so that the white wood could be seen everywhere. The trees were covered again with new bark. Frisch assures us that this experiment will always succeed if made at the time of the solstice and if the exposed outer surface, over which the sap is spread uniformly with a feather, is protected by linen or split cane against the sun and wind*.

The celebrated experimenter, Duhamel[2], removed a ring of bark from several young trees, elms, plums, etc., 7 to 10 cm. wide down to the wood, at the time when the sap was flowing and surrounded the wounds with glass cylinders. which were closed at the top and bottom against the uninjured part of the trunk with cement and tissue. He found delicate, jelly-like warts forming on the exposed wood surface, and pushing out between the wood fibres of the sap wood (des mamelons gélatineux qui sortaient d'entre les fibres longitudinales de l'aubier). These little warts, which push out under very tender, probably left over, phloem lamellae, were at first white, and half translucent, later gray, and after 10 days (on April 18th) green. These new structures, broadened in the course of the summer and finally uniting, produced a rough bark beneath which delicate wood lamellae were recognizable. "Ainsi il est bien prouvé que le bois peut produire de l'écorce et que cette écorce est des lors en état de produire feuillets ligneux . . . "

Knight made similar experiments and obtained similar results. He found once[3] on *Ulmus montana,* a regeneration of the bark when the wound had not been covered. The tree grew in a shady place. Knight found in old topped oaks, with an incompletely formed new bark growth, that the jelly-like warts had pushed out from the parenchymatous cell tissue and "in many cases new bark was formed in small and isolated portions only on the upper surface."

Meyen[4] quotes Werneck's observations, according to which the regeneration of the bark will take place only if the barking happens about the 25th of June, when the trunks are still young and the wounded place is "very carefully protected against drying by a hollow and closely adjusted bandage."

We find Meyen's own theory[5] in the description of his experiments given in his *Phytopathology.* On April 30th, 1839, in warm sunshine he

1 Treviranus, Physiologie der Gewächse, Vol. II, 1838, p. 222.
2 Duhamel, Physique des arbres 1758, Vol. II, p. 42. Vol. VII, p. 63, and loc. cit., p. 44. Vol. VIII, p. 66, 67.
3 Treviranus, loc. cit., p. 228 (Beytr. 228).
4 Meyen, Neues System d. Pflanzenphys. 1837, p. 394.
5 Meyen, Pflanzenpathologie, published by Nees. v. Esenbeck. Berlin 1841, p. 14.

* Miscell. Berolin. Contin, II (1727), 26.

removed the bark from the little trunks and larger branches of the hazlenut, the snowball, Syringa and willow and, like Duhamel, enclosed the barked places with cemented glass tubes, which in addition were wrapped with paper, although he made the experiments in thickly shaded places. Jelly-like drops were "sweated out" here also, "which always occurred on the places where the medullary rays appeared on the upper surface of the wood."

Microscopic investigation of this "sweating" showed the warts to be composed of tender cell tissue, "which enlarged constantly because of the gum in the sap, exuded by the medullary ray cells."

The greenish color, which these new structures assume, arises from the chlorophyll grains. In the course of the experimental year these structures reached a thickness of 11 mm. but shrivelled greatly when dried.

Meyen cannot ascribe the significance of bark to these new structures, which are also produced naturally in shady places[1]. For "no separation into different layers, of which the normal bark of the same tree is composed, can be seen and moreover there is no trace of sieve tubes in it, which are, of course, very important . . . "

This physiologist, very distinguished in his time, who according to the Mirbelian theory considered the cambium to be a structureless sap, which brought forth such cell structures as those from which it had appeared, has indeed the merit of having made use of the microscope to investigate the new structures which appeared with the healing of bark wounds. He was not fortunate enough, however, to observe the production of wood among these new structures and to prove the analogy between these forms and normal bark.

Probably the moist air and heavy shading from his cylinder were to blame, since as we shall see these factors influence considerably the character of the new structure.

Dalbret[2] experimented earlier than Meyen, for on the 21st of June he barked an ash and a walnut, enclosed the barked places in a cylinder and obtained the same results as Duhamel.

Th. Hartig[3] in the spring of 1852 at the time the new annual rings had begun to develop removed the bark from 30 to 40 somewhat older oaks for 6 to 8 meters above the ground and in August found the majority of the mutilated trees bore as dense foliage as the adjacent ones from which the bark had not been removed. On 5 or 6 young trunks a scabby eruption, pressed out from the medullary rays of the wood, had formed "curiously" only on the sunny side. Anatomical investigations showed that the eruption, quite independent of the phloem and cambium, had come from the wood alone and was a product of the medullary rays.

[1] Pflanzenphysiologie, Vol. 1, p. 390.

[2] Journal de la société d'agronomie pratique 1830; quoted by Trécul in "Accroissement des végétaux dicotylédonés ligneux." Annales des sciences natur. III, Serie, Vol. XIX, Paris 1853.

[3] Th. Hartig. Vollst. Naturgesch. d. forstl. Kulturpfl. Deutschlands. Berlin 1852. Explanation of the figures (plate 70, Figs. 1-3).

The new structure begins with the appearance of a layer of cork cells at the periphery of the healthy medullary ray tissue, cutting off an outer, dead part. The living part of the medullary ray now develops several layers of parenchymatous cells about its circumference, which cells turn green like the medullary tissue already present. By the increase of the parenchymatous tissue around the medullary rays, a callus roll is produced, which rapidly becomes larger and constantly presses farther outward the cork layer which begins with the formation of lenticels. "The new cell tissue does not develop on any one place from the living medullary ray, but as everywhere new cells are formed in all places inside the cells already formed; these reabsorb the mother cell, grow out to its size and widen the mass on all sides. In spite of the widening of the callus, due to the growing cell tissue, the living part of the medullary ray, nevertheless, always retains the same circumference, the same size, number, form and position of the cell tissue constituting it."

"When the callus reaches a certain size, different parts become unusually thick walled, as is also the case in the normal course of the life of the bark (stone cell aggregations). Further, on each side of the living medullary ray not far from its tip, a vascular bundle develops in the cell tissue, which consists of pitted tracheids and vessels between the medullary ray and the cork layer." By the fusion of the individual coördinate tissue zones of the new structures, which up to that time had been completely isolated and wart-like, a continuous bark layer covered with a cork layer is produced, differing only by the radial arrangement of its cell elements in cross section from the structure of the normal bark. "Along the sides of the tip of the medullary ray, the development of the wood advances up to the formation of a connected wood layer, traversed by the cell tissue of the old medullary rays just as by newly formed, smaller ones. The various wood bundles consist of tracheids and fibres. True spiral elements are lacking. A line of division between the wood and the bark (Meristem zone Ref.) is formed more and more sharply with the advancing development of the wood, although no trace can be discovered either of phloem fibres or of sieve tubes."

Th. Hartig's observations, which represent an important advance, show, therefore, that the development of the new bark on a bark injury, takes place at the expense of the nutritive substances present in the wood and begins with the formation of a callus tissue around the tips of the medullary rays.

It cannot be learned either from the description, or from the drawings, which cells initiate the callus formation.

Trécul[1] fills this gap with his thorough anatomical investigations, which prove at the same time the participation of the *whole young tissue left on*

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[1] Trécul, Accroissement des végétaux dicotylédonés ligneux. Annales des science. nat. XIX, p. 165.

the barked wood stem and not merely that of the medullary rays in the formation of callus. Nevertheless, under special conditions the medullary ray cells can alone cause the formation of callus and yet the case often occurs where the callus formation is initiated by the young wood cells alone.

The young wood cells, the medullary ray cells and the narrow elements participate in the callus formation by a transformation into parenchyma cells which now increase in number[1].

The youngest cells, left on the wood cylinder, widen, elongate and divide. The end cell of the last row of callus cells becomes largest. It is often spherical, or club shaped, and the new cross wall is produced generally in this stage. The new end cell now formed by the cross wall repeats the process. The older cells, lying back of it, elongate and divide.

Besides this kind of callus formation, Trécul observed still another case. While the outermost remaining cells develop into callus tissue, by distention and division, it also happens that they show only a slight development, while the innermost young wood cells, *lying beneath them,* take over the rôle of the actual callus former. Trécul sketches (pl. 7, Fig. 11) a longitudinal section of the elm, the callus on the edge of which consists of short, isodiametric cells. This gradually drying layer has been pushed up from the wood by means of a thick callus layer, of which older cells now adjoin the wood. The youngest cells most distant from the old wood, lying directly under the outpushed dying layer, have stretched radially and formed radially parallel rows.

Both cases of callus formation can occur at the same time in the same specimen. Probably the innermost layers of the exposed cambial body are incited to increase by the drying of the outermost layers.

As my experiments show, all the cells of the cambial region can participate in the callus formation, not only the young wood cells, as de Vries thinks, but also the young bark cells. It depends alone upon which cell layers are left when the bark is removed. If it is loosened in such a way that only a few of this year's sapwood cells still capable of increase remain on the old wood, the callus must be formed from them; if, on the other hand, the very youngest cambium cells remain in place, they take over this formation of callus, while the underlying young sapwood develops, according to its position, into differentiated wood with vessels and is changed only in so far as all its elements become shorter, broader in the radial dimension and thinner walled.

Trécul[2], in his Fig. 5, pl. 3, of a linden, gives the best example of this case. We will use this (see Fig. 186) to confirm our theory. *B* indicates the young wood of the current year formed before the removal of the bark,

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1 "Les fibres ligneuses, les rayons médullaires et les vaisseaux d'un petit diamètre eux-memes sont métamorphosés en tissu cellulaire proprement dit; car il y a une métamorphose réelle de ces organes elémentaires en tissu utriculaire ordinaire, et ensuite multiplication de ces utricules nouvelles.

2 Trécul loc. cit., p. 167.

with its vessels (v). A to A', according to Trécul, is the old bark of the previous year[1]. The split, which pushed up the bark, extends horizontally above the highest vessel (v) to the point marked x'; from there it runs downward toward the right almost to the thin-walled, last-formed cells of the previous year, so that the whole group (g) should be considered as a new structure. At x, the loosened bark has removed only the outermost layers of the youngest wood, or has possibly extended only to the central cambial zone, so that the whole sapwood has remained in place. The outermost cells elongate (l) and divide (l'). The upper cell (r) of each row, cut off by the new wall, repeats the process.

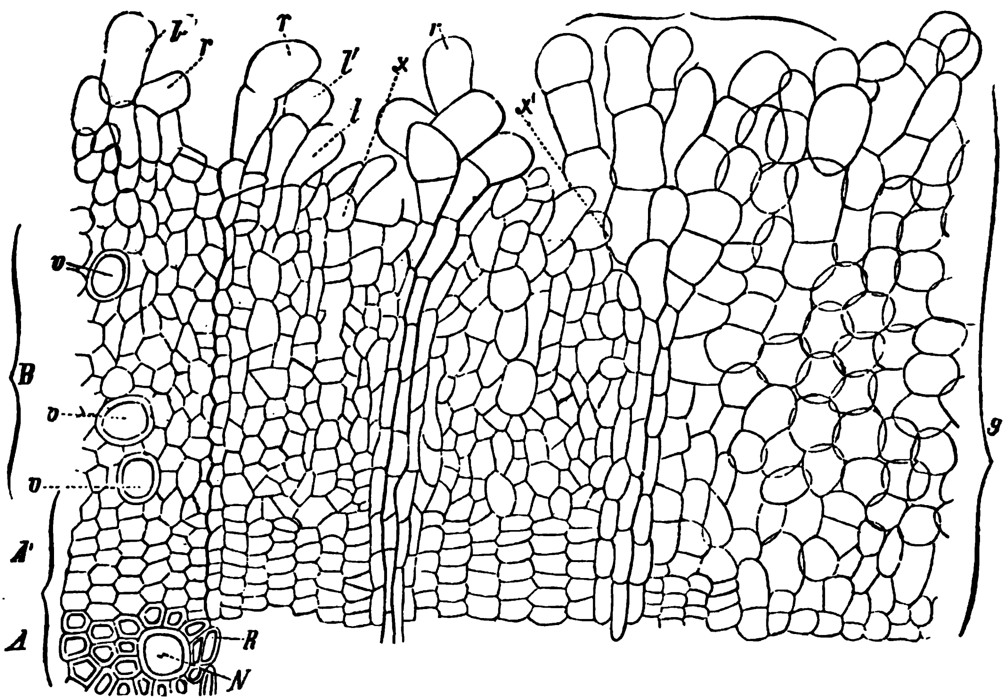

Fig. 186. Callus formaton from young bark cells in a barked trunk. (After Trécul.)

The young wood (sapwood) has been stretched radially by the injury, i. e. by the removal of the bark pressure. It forms shorter cells with wider lumens but has remained thin-walled, while the vessels already started have matured.

From x' out, the young sapwood has been removed with the loosened bark and on the wood of the previous year only a few young wood cells of the current year were left. These cells have now taken over the formation

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1 It might seem strange that the annual ring at A' ends with a very thin-walled spring wood, but such cases actually occur. I obtained from the Eifel in January larches diseased with canker, the annual ring of which had formed over the summer wood a layer six cells thick of thin-walled spring wood.

of callus, which naturally lacks vessels, though it reaches the thickness of the adjoining parts by a more rapid increase in the lumen of the cells[1].

Opinions differ greatly as to the life period of barked trunks.

The best example of an unusually long life period in trees which have lost their bark extensively, and have not replaced it, the exposed wood consequently falling victim each year to decay, is furnished by Trécul in his description of the linden at Fontainebleau[2]. Yet we have still earlier observations.

In 1709, Parent reported the following observation to the Academy: An elm in the Tuileries, which at the beginning of spring, 1708, had lost *all* its bark nevertheless developed its leaves, even if somewhat less vigorously, and kept them all summer.

Duhamel[3] expresses himself as follows in this connection: Trees with bark wounds, which remain uncovered, gradually go to pieces (sometimes not until four years later).

At the sitting of the Academy on May 11th, 1852, Richard related a case, similar to the one described by Parent as something very extraordinary, since, in the majority of cases, the trees die soon after such injuries.

Gaudichaud[4] disputes this latter statement by referring to trees in St. Cloud, in the Luxembourg, and at Fontainebleau, which after such injuries lived a great many years, although the outside of the exposed trunk was partially destroyed.

At the sitting of the Academy of March 7th, 1853, the same botanist returns to this point and now cites the linden at Fontainebleau. According to Trécul, this tree was planted about 1780 and in 1810 was very irregularly barked by some dump carts. On the north side, the barked place was 32 cm. long, and began 57 cm. above the ground, while on the south side it was 4.05 m. long and began immediately at the surface of the soil. The barking extended completely around the tree and yet, despite this, the tree lived for 44 years (it did not die until 1854). The diameter at the place of injury was 20 cm., below it, 18 cm. The surface of the injured trunk, the centre of which was so cut by the carts that the diameters of the remainder were 10 and 5½ cm., was entirely worm-eaten and dry. After the dead wood had been removed, the remaining living central portion was

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1 To characterize Trécul's theory, we will give his explanation of the figure, loc. cit., p. 191: A, A' bois de l'année précédente, V, vaisseaux de ce bois; R rayons medullaires—B jeune bois formé au printemps avant la décortication. Tous les éléments de ce jeune bois, et la partie la plus externe A' de celui de l'année précédente, ont subi un amincissement dans leur membrane. Les cellules externes des rayons médullaires R ont donné lieu à une multiplication utriculaire, quelquefois abondante en r. La multiplication commence aussi en l, l', dans les éléments du tissue ligneux. En g, cette multiplication s'étend à toute la couche l'année et même aux fibres ligneuses les plus externes A' de l'année précedente. Les vaisseaux qui existaient primitivement dans la couche de cette année, comme en B, v, sont disparu en g.

2 Trécul, M. A., L'influence des cortications annulaires sur la végétation des arbres dicotylédonés. Annales di. scienc. nat., IV Serie, Vol. III, Botanique 1855, p. 341.

3 Physique des arbres, Vol. II, p. 46.

4 Compt. rend. (from 31st of May, 1852).

found to be only 2½ cm. thick; it was very juicy and looked like young wood. Almost all the root nourishment for the top of the old tree had to ascend this slender cylinder, and yet in the year observed, viz: March 29, 1853, the top developed just as early and had as many leaves and blossoms as the other lindens. But this tree, which at its base had sent out a number of branches and leaved sprouts 5 to 6 cm. thick lost its foliage in August.

Trécul ascribes to these shoots the maintenance of the basal part of the trunk, below the barked place; they prepared for it the plastic material which a normal trunk receives from the top through the bark.

Lindley[1] describes an analogous process in a birch branch which had been completely robbed of bark and sapwood near the place where it joined the tree and yet had continued to grow for several years.

Th. Hartig[2] found that a linden, from which a ring of bark had been removed, was still alive 9 years after the operation; in fact, its fertility was increased.

The court gardener, Reinecken, in Greiz, reports a grafted elm 10 cm. in thickness, which for 6 years was connected with its stock only through the wood and not through the bark. The Inspector of the Gardens, Roth, in Moscow, also found a red beech 75 cm. thick and 25 feet high, which for 45 years had never been connected with the parent trunk by the bark (as Göppert states) but was connected only by the wood layers. Nevertheless, it grew vigorously and was finally broken off by the wind. In the botanical garden at Breslau, a linden 14 m. high and one-third meter thick blossomed every year. Its bark had been removed completely and carefully in 1870 for a distance of one-third meter, and above the barked place, an overgrowth layer scarcely 2 cm. long had grown in the first 2 years[3].

The result of the barking cannot be determined in advance. The life duration in the barked trunk depends considerably on the variety of tree. Rapid growing, deciduous trees best endure such extensive injuries. Satisfactory results have not as yet been reported for conifers. Hartig[4] did not find any new formation of bark but discovered that the piece of the branch below this barked place down to the next lower branch had developed into very resinous wood. Stoll[5] also could find no regeneration of bark. He states, however, that Nördlinger had observed a new formation of bark but had expressed the opinion that the newly formed bark was not capable of conducting the descending sap current.

Stoll states of monocotyledons that he found a cicatrization of wounded surfaces in a Dracaena, from which he had removed the bark. It was kept in a greenhouse.

The resulting phenomena depend not only on the plant variety but also on the time of the manipulation and the ease with which the individual can

1 Gardener's Chronicle of Nov. 13, 1852, p. 726.
2 Hartig, Th., Folgen der Ringelung an einer Linde. Bot. Zeit. 1863, p. 286.
3 Göppert, Über das Saftsteigen in unseren Bäumen. 57. Jahresber. d. Schles. Ges. f. vaterl. Kultur 1880, p. 293.
4 Folgen der Ringelung an Nadelholzästen. Bot. Zeit. 1863, p. 282.
5 Über Ringelung. Wiener Obst- und Gartenzeitung 1876, p. 167.

produce accessory organs in the form of adventitious buds and roots. In fruit culture, the girdling process is used only as the most extreme means of obtaining the setting of fruit in trees exhausted by a too vigorous formation of wood.

PERSONAL OBSERVATIONS.

To test the processes described by earlier observers, the bark was peeled from a considerable number of strong, about 5 year old, sweet cherry tree trunks in July. The upper and lower parts of the barked places were scraped for a length of 2 to 4cm. with a knife to destroy the sapwood; the remaining part of the exposed surface was left untouched (see Fig. 187). Some of the experimental saplings grown on open ground were bent from their natural, vertical position to one inclined toward the ground.

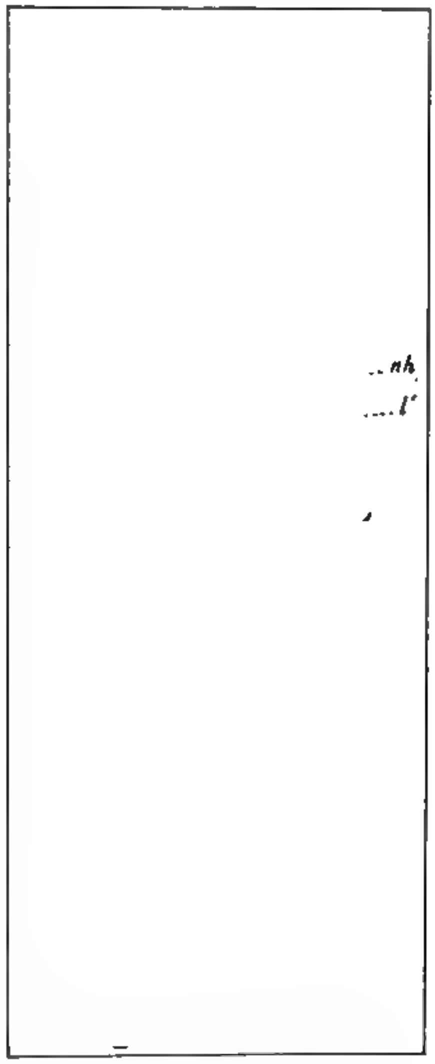


Fig. 187. A barked trunk of a sweet cherry. All young tissue has been removed from the upper and lower edges of the place barked.

The formation of new bark did not take place in all specimens, but in a few it occurred to a considerable extent. Among the latter were found some small specimens which had formed new bark on all sides with the exception of the perfectly dry, scraped places near the upper and lower edges of the cut. The new bark, therefore, had no connection whatever with the old bark. The initial stages had appeared simultaneously on all sides. The thickness of the new bark, however, was more than twice as great on the lower part of the exposed surface as on the upper part; in fact, at the lower edge, it had spread in short bands with wartlike thickenings in places on the scattered scraped areas. In an inclined trunk the continuation of the bark had turned away from the scraped place and started to grow down toward the ground, as Fig. 187 *e'* shows.

In Fig. 187, *u* is the lower and *u'* the upper overgrowth edge of the peeled surface. This overgrowth edge, which in structure resembles the callus of the grapevine, has not been developed all around the trunk, since

a part of the bark has been left standing in the loose strips *l* and *l*. New wood with bark (*nh*) has been formed in places on these strips at a little distance from the place of their attachment. The real exposed surface of the trunk has been cut off from all connection with the overgrowth edges *u,u'*, because at *i* and *i'* the young wood, as already mentioned, had been scraped off all around the trunk, in this manner forming an isolating band. The new formation of bark elements with the beginnings of wood had started on the exposed surface, cut off from all connection with the bark and sapwood layers. These new structures do not form a connected mantle but consist of isolated groups. On other, more carefully barked trunks,

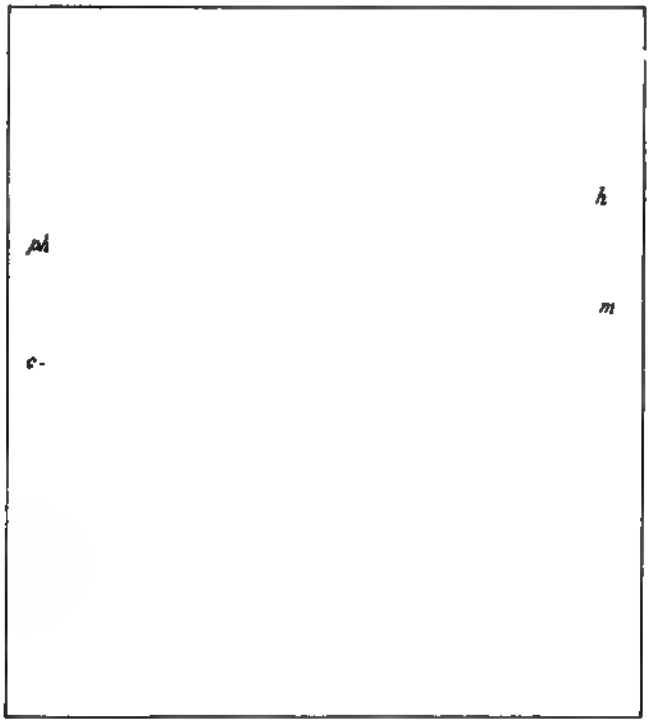


Fig. 188. Cross-section through a newly produced tissue outgrowth on the exposed wood of the barked sweet cherry trunk.

the new bark extends perfectly uniformly over the bared surface. In the middle of this surface an irregular zone of exposed wood has remained without any new formation. Therefore, the new product (*b*) is not connected with the upper one (*a*), which is considerably thicker. Common to both and just as clearly recognizable in all new structures on other trunks is the thickening which increases from above downward in each individual tissue strip and in its appearance resembles perfectly the phenomenon produced by the drippings of a badly burning candle. In fact, the lower end of the new structure, resembling the callus, is poured in the form of drops over the parts of the wood which have remained naked (*ee*). On

the trunks which had been kept inclined intentionally the new structure hangs free from the axis, like the drippings of a slanted burning candle and, in response to the force of gravity, grows downward like an isolated pendent braid, perpendicular to the earth's surface.

In order to show that the various small spots, as has been observed by Meyen, Th. Hartig and others, possibly are not merely productions of the medullary rays, one such structure is shown in cross section in Fig. 188, and in longitudinal section in Fig. 189. Fig. 188 *H* indicates the old wood, the barked surface of which (*t* to *t*) is partially dead; only the middle portion has started new production (*N-N*).

The production began with a raising of the outermost cell layer by the rapidly forming products of division of the immediately underlying sap-wood layer and, in fact, also of the young wood cells together with the vessels and the medullary ray cells.

After the cork zone (*k*), which is becoming thicker, has surrounded the comparatively scanty new parenchymatous tissue (*r* to *p*), an inner meristem zone appears very early at first in bands and then connected. This meristematic zone is new cambium (*c* to *c*), which now takes over the secondary growth of cork.

In this way the two processes of growth, which can take place in the formation of bark on barked surfaces, differ considerably. If, as is the case in enclosed wounds, which have been kept moist, the new bark begins with a great production of callus, together with a long continued division of the peripheral cells, as Fig. 186 shows, the formation of the outer cork zone and especially the production of the inner meristem zone takes place very late. In contrast to this, as in the present case, *the wounded places which have been exposed unprotected to the hot summer sun show the second process,* since the outermost remaining cells quickly thicken their outer walls, collapse and in this way furnish for the immediately underlying layers the necessary protection against drying. In this only a slight formation of parenchyma, but a very rapid appearance of the cambial zone, takes place. It seems that the *inner meristem zone has developed the more quickly into a callus the more rapidly a sufficient bark pressure is produced by suberization.*

The next production of the new cambial regions (Fig. 188, *c-c*) consists in the formation of isolated new vascular bundle strands, which, beginning with scattered short vessels (*g*), rapidly increase with age the number and size of their elements and thus assume a wedge-like form which constantly narrows toward the medullary ray regions (*m*) and at the beginning is very broad, until structure and arrangement of the elements have reached the normal stage of the unbarked trunk. To each xylem part belongs a phloem part (*ph*), near which appear numerous cells containing calcium oxalate (*o*).

We see that the appearance of the vascular bundles in the parenchymatous ground tissue is the *same as in the callus.* This is true wherever

a parenchymatous ground tissue of considerable extent has been formed. By cross-division of a number of cells which at first do not differ in form from the ground mass and are but slightly elongated radially and longitudinally, a number of meristematic centres are formed from which the beginnings of thick-walled tissue elements start. By a very luxuriant callus-like cell increase from the beginning, two parallel zones of meristematic strands can be produced simultaneously, with the tissues as they grow older. These parallel zones mature into two wood areas, which remain distinct until they have become very thick. The formation of

Fig. 189. Longitudinal section through the basal part of Fig. 188, about in the zone to be found from g to p.

isolated vascular bundles in the bark of our trees is not rare as is said to be shown in tuber-gnarls.

The first processes of change in the sapwood of the barked cherry tree may be recognized in Fig. 189, which gives a longitudinal section from the base of the barked portion in Fig. 188. *H* is the old wood, which because of the cut has not changed any further, with its loosely reticulated vessels (*g*). In the sapwood, lying just outside it, the cut has so affected the nearly mature vessel (*g*) that its ***inner cavity has become filled with tyloses; these have been used to form new cells*** and been changed into wood parenchyma. The new layer of wood parenchyma consists of only a few cells

and exhibits immediately the first stages of thicker walled elements in the form of shorter, porous vessels (*gz*) as the first production of the newly formed cambial layer *c-c*. Each successive tissue layer, formed from the cambium, has longer vessels; at *h*, we find thin-walled elements, shortened, to be sure, but unmistakably resembling the normal wood cells; corresponding to these thin-walled elements, the phloem elements appear at *s* in the bark (*r*) : *x* is the xylem ray, *ph* the phloem ray.

If in the early spring, when the bark is easily loosened, homologous cells are torn around the whole circumference of the trunk in the process of removing the bark, thereby causing a reproduction of similar bark, arising from similar elements, we find that the bark wounds become more irregular from the time of the leaf development until late in June. More cell groups remain attached to one place on the wood cylinder than to another and the new structures differ accordingly. It thus happens that pieces of sapwood of the current year, which contain vessels, are forced up by a callus tissue produced beneath them.

If the bark wounds are left uncovered, the new formation of bark will in many cases be more doubtful. According to my experience, the bark regeneration succeeds better in July, for some trees in August, than in April, May or June. The maple and alder must be barked earlier; numerous experiments made on these trees in August gave no results at all.

If the bark wound, made in the heat of the day and left without any protection whatever, is investigated after some hours (sweet cherry trees were used for the experiment) it was found that the color of the originally white wood cylinder had changed to yellow. The wound surface owed this color especially to the browning of the medullary ray cells.

The browning is more intense on the southwest side than on the north side.

The medullary rays are easily recognized by the fact that immediately after the removal of the bark they project somewhat above the barked surface.

This fact indicates that the medullary ray cells at the same radial distance from the median line of the trunk have firmer walls than the young wood cells, i. e. their development is further advanced than that of the equally old cells of the vascular bundle.

Such an advance of the medullary rays over the other tissue *will stamp them as a tissue of increase, which creates space for the newly produced wood tissue in the direction of the radius of the trunk.*

This prominence of the medullary ray groups takes place also in part because of the more rapid outcurving of their outer walls, resulting, as a rule, from the barking. These outer walls (unprotected) grow thick very rapidly and turn brown.

The cell contents increase in the medullary ray and young wood cells lying immediately beneath the wound surface; masses of cyptoplasm and later of starch appear, the former, when treated with glycerin, rounds up

into scattered yellow globules. Beneath the outermost cell layer, which at once collapses and forms a protective mantle for the underlying young tissue, the new cell formation begins by means of cross walls. The medullary ray, the cells of which as a rule are in advance of the others, is frequently broadened by this new formation since the later ray cells push out in a fan over the adjoining wood cells.

It has already been stated that often the medullary ray cells can remain partially or entirely undeveloped. Then the parenchymatous callus cells, which are never round but always polygonal, and are produced from the young wood fibres, spread over the medullary ray groups. As a rule, however, the whole tissue participates equally in the formation of a thin callus layer which pushes out the outermost cells of the old wood. By drying these old cells produce a protecting layer.

While the callus formation through the excrescent apical growth of the various cell rows is very considerable in the barked places, which are kept protected and moist, it is very small in unprotected places. Cork is formed at once beneath the dried, outer cell layer and becomes a constricting, firmly protecting girdle for the underlying young tissue, which is turning green.

The new formation of bark on barked places may occur in still another way. If the bark wound is made in such a way that young bark cells form the outermost layers of the exposed surface, they initiate the callus formation and the real cambial layer is only slightly disturbed.

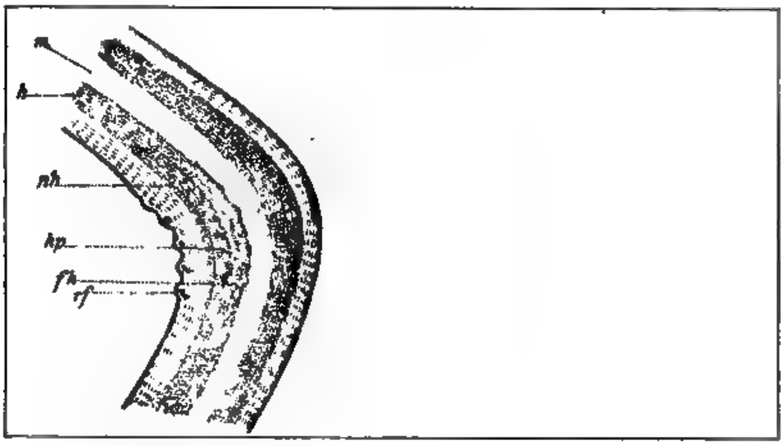
The transition of the callus into normal tissue takes places in general in such a way that isolated, short celled, vascular strands occur deeper inside the callus after the cork cells have begun to form about its edge. About this time thick-walled, slightly porous, irregular, or polygonal cells are found, possibly in the same radial direction but more in the vicinity of the peripheral zone of the callus. These cells are the first traces of a phloem formation. In many trees, the first phloem elements in the form of aggregations of stone cells are found isolated or soon united into groups. In one zone, cells with a cloudier, denser content are found between the phloem and the vessel elements. In them occur a great many rectangular walled cells, somewhat stretched in the direction of the long axis of the trunk, which might be the very first stages of *the newly forming cambium.* From this cambium are produced gradually the elongated elements which finally develop into normal wood and fibres but no more long, spiral elements seem to be formed.

With the development of these normal fibres, the last to appear, the new bark may take on the function of the uninjured bark.

The Bending of the Branches.

Branches are often bent as a special aid in fruit culture. Experience shows that shoots which grow upright develop most quickly and strongly and that their growth in length will be the more retarded, the further the

branch inclines from the vertical toward the horizontal. The same retardation of the apical growth is found, however, if branches are bent artificially from a natural horizontal position toward the downward perpendicular,



Figs. 190 and 191. Artificially bent apple twig in longitudinal and in cross-section.

from which it is evident that the bending itself exercises the arresting influence.

No externally perceptible wound is produced if the manipulation is carefully carried out, though a somewhat greater tension may be seen on the upper side and a folding of the bark on the under side.

Fig. 192. Fold in the bark on the under side of the bend.

The development of the buds is affected by the bending, since the buds below the place of bending swell up more and, not infrequently burst prematurely. The success depends upon the time and place where the branch

is bent. The nearer the tip of the twig the bent place lies, the less the internal injury is, but also the less the desired result. The buds beneath the place bent will then develop into slender leaf shoots. But when the branch is bent near its base the buds stimulated to growth will develop only short shoots; these, however, show a tendency to change to fruiting wood.

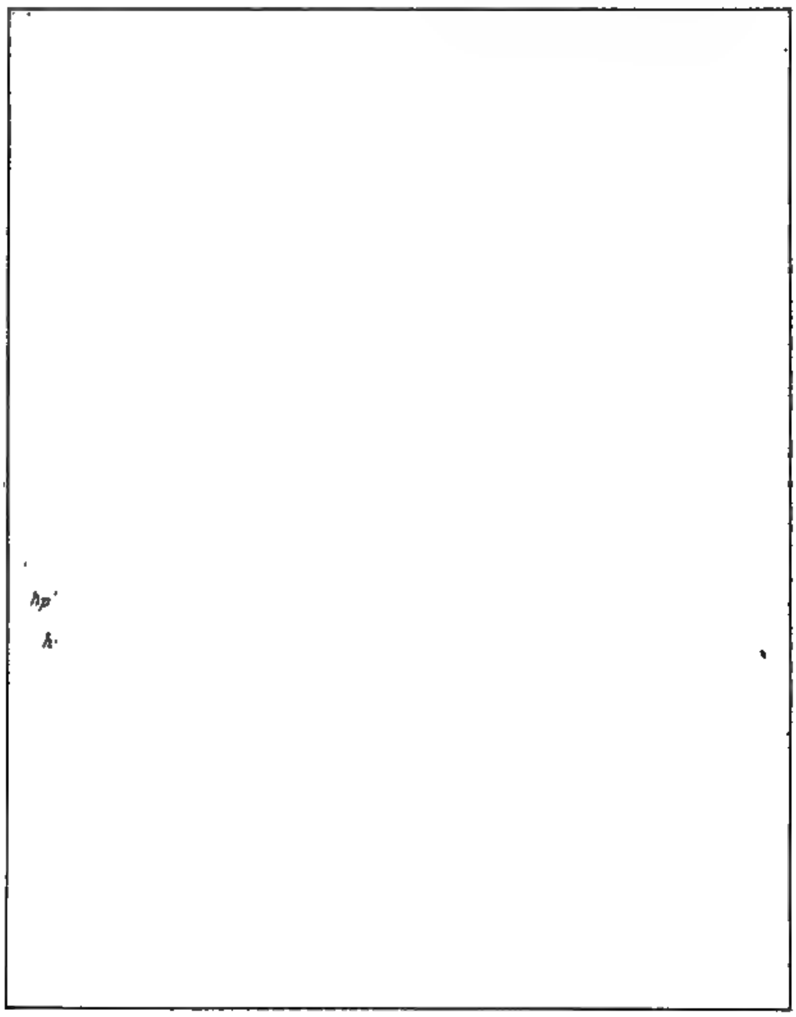


Fig. 193. Longitudinal section through the wood within the bend.

We have spoken above of an internal injury to the axis even when carefully bent. This is best seen in a definite example as shown in Figs. 190-194 of an apple branch.

The folding of the bark is indicated in Fig. 190 (*rf*) and Fig. 191 (*rf*). Upon examination with the naked eye, one sees first of all a swelling of the wood on the under side, below a pale, brownish zone, widened at the place of bending (Figs. 190 and 191, *hp*), in the longitudinal section (Fig. 190 *h*)

and in the cross section (Fig. 191 *u*). Except for the folding of the bark body no perceptible uniformly increased thickening is seen in the wood.

In the apple branch here drawn the proportion of thickness between the bark on the under side and the upper side is 50 to 42, while that on the under side of the wood is 2 to 1. The pith (*m*) seems in the longitudinal section slightly brown in stripes, especially in the lower half. Under the microscope many of the cells of the pith and the pith crown, often arranged in wavy lines, are found to have a brownish content and browned walls which, in various cells belonging to the under side of the pith, are sharply bent here and there and at these places separated from one another by newly produced intercellular spaces (Fig. 194). The cells show the same separation even in the cross section.

The disturbances to the bark may be recognized most easily in the projecting folds of the under side (Figs. 190 and 191, *rf*). In such folds, split off from the wood by the bending, the phloem bundles (Fig. 192, *hb*), as a rule, show a marked outward curving, corresponding to the peripheral cork layers (*k*) produced in considerable thickness by the squeezing of the epidermal cells and corresponding also to the bark parenchyma (*r*), which has been broken up by numerous holes (*l*) into irregular particles. Some time after bending some bridges of radially elongated cell rows are found in these holes, produced by the elongation of the still elastic cells of the young, inner bark.

Fig. 194. a pith cells which have been broken apart in the bending; b those which have remained uninjured.

The apple branch in question was bent at the beginning of summer as is generally done in practice. The bark has been pushed up from the wood at the above described folds in the cambial region. The relief from bark pressure at these places has resulted in the formation of an abundant wood parenchyma, filled with starch, as shown in the longitudinal section through the wood (Fig. 193 *hp*). After the holes have been filled in and the bark pressure re-established, the wood parenchyma has gradually changed into normal wood (Fig. 193 *hh'*).

The filling of the holes takes place here after the coalescence of both parenchyma parts growing toward one another and uniting in the medial zone (*z*). This yellow colored zone, under strong magnification, resolves itself into a stripe of closely compressed cells. In other cases, the filling of the holes is produced also by new parenchymatous structures from the raised bark zone as well as from the remaining young sapwood tissue (as in bark wounds). In all cases vessels first begin to appear in the wood parenchyma after the holes are filled out; they gradually reach their normal length and development, are accompanied at first by shorter, thinner-walled wood cells, later by normally long and thicker-walled ones, and thus the normal wood formation begins.

After these wounds are closed, the influence of the bending is still always noticeable in a production of wood which takes place more vigorously on the under side than on the upper side. The arrangement of the newly formed wood (Fig. 193 *h*) follows, on the under side, the wavy line caused by the cone of parenchyma wood (*hp*). In contrast to the scantier, simultaneously produced elements of the upper side of the bent place, the prosenchyma cells of the under side are at first shorter and arranged bluntly against one another, with broad walls. Further, more abundantly divided wood cells and rows of wood parenchyma (*hp'*), filled with starch, are found on the under side between the thick-walled parenchymatous elements.

On account of the limited space considerable parts of the tissue have been omitted in the drawing; also part of the normal wood, formed before the bending, as well as a part of the transitional tissue produced after the formation of the wood parenchyma and equalizing the bending. In Fig. 193, *fh* indicates the spring wood of the current year, *g* the spiral elements bordering the pith (*mk*). In Fig. 194, *a* indicates the pith cells, which have been loosened by the bending; *b*, those which have remained uninjured and originate from the upper half of the pith body.

If the bent twig is investigated above and below the bend, it is found that in the present case the influence of the bending extends on an average over 6 to 8 cm.

The measurements of the branch, chosen for the drawings, are as follows:

Its thickness amounted to 4.65 mm. beneath the bend, 5.50 mm. at the bend and 5.06 mm. above it. The bark showed toward the tip a considerable increase in thickness.

The thickness of the wood, before the treatment, amounted to

Below the bend	upper side 62.0 per cent.		of the wood cylinder existing at the time of the measurement, and strengthened by subsequent growth.
	under side 61.9	"	
At the bend	upper side 50.6	"	
	under side 35.2	"	
Above the bend	upper side 67.4	"	
	under side 51.4	"	

The increase in growth from the time of bending up to the time of investigation amounted to

		Autumn Wood	Spring Wood
Below the bend	upper side	31.0 per cent.	8.0 per cent.
	under side	31.9 "	6.1 "
At the bend	upper side	39.0 "	10.4 "
	under side	51.8 "	13.4 "
Above the bend	upper side	28.1 "	5.9 "
	under side	27.2 "	21.9 "

Therefore, the increased wood growth is comparatively greater on the ----- side of the bend than above and below the bent place in spite of the sion which may prevail on the convex side within the bend due to

the bending of the branch[1]. The loosening of the tissue, manifested at the bend, can no longer be recognized on the upper side. On the other hand, on the under side it may be traced for 6 cm. toward the tip.

The wood cells are the widest at the bend but are wider above it than below it; they seem to be wider on the under side of the branch than on the upper side.

The anatomical changes vary in quantity according to the size of the curve, which the twig describes when bent, as well as the time of bending, the species and, indeed, the individuality of the branch.

Therefore, one has in the bending of branches a simple means for moderating the growth in length and for directing the supply of water toward the buds which, because of their position and nature, are capable of little further development.

The Twisting of Branches

The effect of twisting the branches is much more pronounced and persistent than that of bending, but follows the same general principles. It represents a further cultural method for the fruit grower, when he wishes to change the growth of branches. During the period of growth, a too luxuriantly growing branch is first loosened in a short woody region by a half turn of the tissues about their long axis; hereby the tissue is usually crushed and split longitudinally and then bent at this broken place, with the tip of the branch downward, so that the tip is permanently bent toward the base. Thus at the place of twisting the under side of the branch lies on top; the former upper side forms the inner side of the sharp bend, in which the wood is broken down to the pith.

Fig. 195. A branch bent with its tip downward and twisted at the point of bending about its longitudinal axis, after the coalescence of the inner injuries.

The most comprehensive view possible of the changes produced by twisting is given in the longitudinal section through the knotty, deformed place of twisting, which is a year old (Fig. 195). In this figure, *m* indicates the pith which has been destroyed by the breaking of the wood when twisted; *h* is the wood of the present upper side on which a bud is seen at *a*. Because of the turning of the under side to the present upper side, the wood

[1] On the production of tension due to pressure, compare Ursprung, H., Beitrag zur Erklärung des exzentrischen Dickenwachstums an Krautpflanzen. Ber. d. Deutsch. Bot. Ges. 1906, Part 9, p. 499. Further: Bücher, H., Anatomische Veränderungen bei gewaltsamer Krümmung und geotropischer Induktion. Jahrb. f. Wiss. Bot. 1906, Vol. 43, p. 271.

has been repeatedly split longitudinally, and the "lamellae" produced by the tears have a spiral twist which is indicated by *dd*. The tears are first filled by parenchyma and then the cambial zone, which gradually closes together, deposits wavy layers of new wood (*n*) over the wounds below the unusually strained bark (*r*), which not infrequently splits here and there in spiral, longitudinal cracks.

The original upper side, which has become the under side from twisting, shows still greater disturbances. The wood (*h'*), broken at *w* and partially split off from the pith, ends in a large knot (*u*) due to very irregularly curved particles of wood parenchyma. This knot constantly increases in size with continued growth by the formation of new wood (*n'*).

It is easy to perceive that the nourishment of the tip of the branch must be disturbed by such an injury to the tissues and that the reserve substances, visible as starch in the parenchymatous overgrowth parts of the edges of the wound, must be enough for the use of the immediately adjacent buds. From what has already been said, it is evident, likewise, that besides this increase in nourishment the buds found directly beneath the place of twisting will also profit from the increased water pressure.

The treatment of twisting, as already remarked, is an effective means of retarding the apical growth of a branch to the advantage of the basal buds *without*, however, causing the uppermost lateral buds, lying below the injury, to sprout at once. The lateral bud immediately below the place of twisting, grows out to a new, vigorous leafy shoot only when the injury to the tissues in the twisting has been so great that the leader can no longer receive the amount of water most necessary to replace that lost by evaporation. It, therefore, dries quickly especially if the maniplation is carried out too early in the year. This result is naturally not desired by the grower. A twisting, carried out too late in the year, would not produce an effect sufficient to prepare the basal buds for fruiting buds, but still would arrest the growth of the branch in length and cause a better ripening of the wood so that it will better withstand the winter.

In the propagation of quinces by layering, the branch, which is to be layered, is twisted once about its long axis at the place where it is to form roots in the soil. This kind of disturbance is similar to that in the above-mentioned case; the result different inasmuch as the retarded, descending plastic material is used chiefly for the formation of adventitious roots.

German grape growers in the vicinity of Tiflis are said to *twist the stems of the ripe clusters* and, thereby, obtain a better wine. The changes, initiated by this treatment, dovetail into one another as follows: the supply of water, from the vine to the cluster, is lessened by the twisting of the stem. Consequently, the evaporation greatly exceeds the supply and the juice of the berries becomes more concentrated. Whatever starch happens to be in the stem is carried as sugar to the berries. They break up and utilize, thereby, a part of the organic acids. The same processes occur in the ripening of cut grapes.

THE EFFECT OF CONSTRICTING THE AXIS.

The "Constriction" consists in the close binding of an inelastic band (i. e. string, wire, etc.) about a trunk or branch. The results of this treatment show, to the casual observer, that this constriction of the axis is nothing but a local, artificial increase of the sap pressure. But here the most extreme case of sap pressure takes effect at once, since the formation of new structures below the constricting place are gradually reduced to a minimum and finally disappear entirely. The xylem elements, near the constricting band, thus deviate from their perpendicular course, even increasing their inclination to the horizontal, so that I think in the different normal trees themselves the more or less *spiral* twisting of the wood fibres is connected with the greater or lesser pressure exerted by the sap.

Finally, the tree becomes so thick above the constricted place that the bark splits above the band and later also below it. This removes the sap pressure almost entirely. The result is a luxuriant formation of wood parenchyma which, with the aging of the plant part, passes over gradually in the later annual layers into normal wood and overgrows completely the band or the wire. Such an overgrown constriction bears great outward resemblance to a grafted place but has naturally no internal structural resemblance to it.

In Fig. 196 (see page 819) two different stages of the constriction are shown. Fig. 196, *1* is a year old maple branch, with a constricted place only a few months old. Fig. 196, *2* is an older branch, which shows the overgrowth of a wire ring, several years old. Fig. 196, *3* is a longitudinal section of Fig. 196, *2*, where *d* and *d'* represent the cross sections of the wire ring; *u* represents the overgrowth edge, which is more greatly developed on one side (*u'*) by the increased supply of nutritive substances from the branch (*z*) above it. Here it has overgrown the wire earlier than on the opposite side.

An anatomical investigation of the stage represented in Fig. 196, *1* shows that the constriction at first cannot produce very extensive changes. The bark has suffered the greatest disadvantage and it is chiefly the cell layers, lying on the outer side of the primary bark, between the phloem fibres, or between the stone cell aggregations and the epidermal cells, which have been especially compressed. The cell layers next the phloem fibres seem to be the most pressed together; the effect is less marked on the next layers toward the outside, which are often thickened like collenchyma. Their cells are compressed to ½ or ¼ their normal diameter and it would seem as if they hereby become somewhat longer than the corresponding cells in an unconstricted place. The sub-epidermal, almost square cells, are compressed to half their diameter. The epidermis suffers least of all.

If, as in Fig. 196, *1*, the constricting band is wound several times about the branch, apparently very prominent callus rolls become noticeable between every two turns. In them the aforesaid parts of the bark are devel-

oped in a way exactly the reverse of that at the constricted place. The cells, bounding the phloem fibres, which in the normal branch are elongated, become considerably broader radially; in fact, they appear like long cylinders, lying perpendicular to the phloem fibres; thereby, the overlying bark tissue, which participates less in the radial elongation, is pushed outward. Moreover, the rolls, lying between the two constricted places, are not absolutely large; they are relatively conspicuous only in contrast to the depressions. The secondary bark and the wood follow the convexities and concavities of the primary bark even if with far smaller variations. The pressure, which makes itself felt in the tissues, acts not only where the band lies on the bark but also somewhat above and below the actual place of constriction; this is seen especially in the cross section of the cells. The mutual proportion in the mean of measurements is:

Normal	In the Bark Roll	Constricted
Fig. 196, *1 n*	Fig. 196, *1 w*	Fig. 196, *1 g*
11,2	11,8	9,4
	In the Wood	
7,3	6,9	4,6

Therefore, according to these mean figures which, moreover, show considerable fluctuation, an increase manifests itself only in the round and apparently broader cortical cells; the wood cells, on the contrary, seem somewhat narrower than those of the normal wood but it should be emphasized that the same maximum diameter of the wood cells has been found in the roll as in the normal part of the branch at some distance from the constricted place and only the frequency of the occurrence gives the decision.

If the constriction becomes older, without the band being broken or loosened, as was the case with the wire band shown in Fig. 196, *2* and *3*, then the pressure of the wire on the layers of the bark finally increases because of the growth in thickness of the underlying wood in such a way that the bark layers are killed and changed into a brown crumbling mass. Finally, the healthy bark splits above and below the wire and inclosure of the wire begins. Because the overgrowing layers of the annual ring are considerably thicker in wood and bark than at places at some distance from the wire, the former constricted place finally projects in a considerable roll.

Fig. 196, *4* shows the section, indicated in Fig. 196, *3* at *a*, considerably magnified. We see here in *longitudinal section* a little of the old wood of a branch (*H*) before the wire (*d*) was bound about it and perceive the new structures of the overgrowth edge at first in the immediate vicinity (*U*) of the wire and then a continuation of these tissues from the older annual layer (*U'*). The transitional stages have been omitted for lack of space, likewise the representation of the coalescence, extending about *U'*, of the very uppermost overgrowth edge with the under one and the representation of the transition from the irregularly running wood elements of the overgrowth

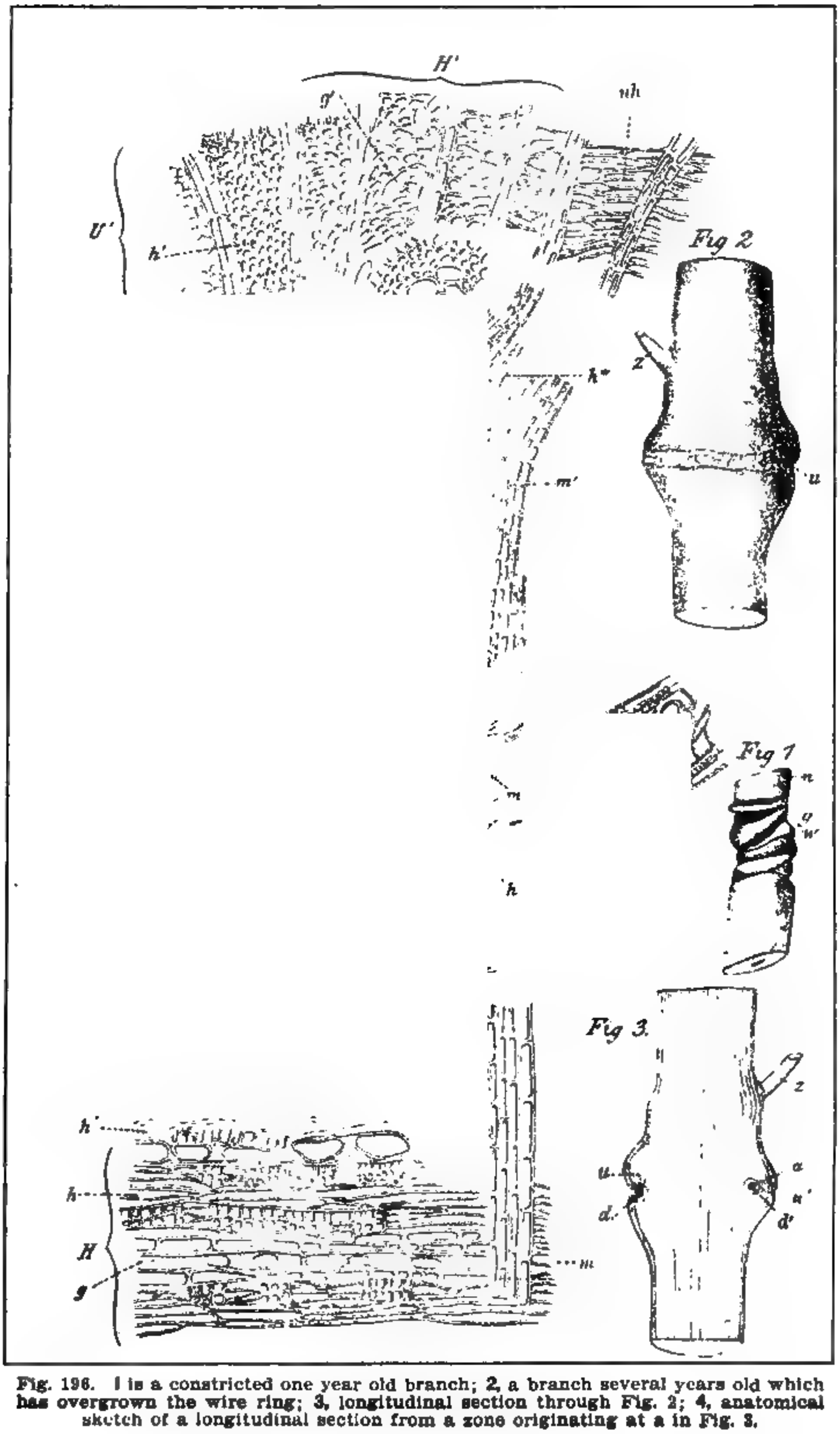


Fig. 196. 1 is a constricted one year old branch; 2, a branch several years old which has overgrown the wire ring; 3, longitudinal section through Fig. 2; 4, anatomical sketch of a longitudinal section from a zone originating at a in Fig. 3.

edge to the normal wood structure, as it gradually forms in the later annual layers above the place where the wire is.

If the wood had grown normally, without the arrestment of the wire, its structure would have necessarily remained the same as before it was constricted, as represented at *H*; wood cells (*h*) with vessels (*g*) would have been formed in regular succession and this broad wood would have been uniformly divided by radially extending medullary rays (*m*). Instead of this, we find the constricted place and above it (*h′*,*h*) a kind of wood produced by the effect of the wire composed almost entirely of wood cells without vessels. Only in the beginning are these wood fibres deposited at *h′* exactly parallel with the long axis of the branch; the more they are found in the direction (*h′*,*h″′*) the more diagonally they run and the more twisted they seem. The wood formed after the wire has been bound on has, therefore, become *denser, poorer in vessels and more twisted.* The medullary rays, which otherwise run as straight radial bands from the pith toward the bark, are as twisted and outspread toward the top as the wood cells, so that a section made exactly in the direction of the radius intersects several of the curved rays (*m″*).

The difference between the wood cells and medullary ray cells is not noticed until at some distance from the wire. In the immediate vicinity of this we find an almost uniform parenchymatous wood (*hp*), of which the edge is dead and black and represents the dark line which may be seen in Fig. 196, *3*, extending upward a little distance from the wire (*d′*). The black furrow no longer extends entirely to the outside, since the later annual layers (Fig. 196, *3*,*u′*) have already united with one another. These overgrowth edges, united with one another to form a common, connected wood layer; are indicated in Fig. 196, *4*, by the tissue *H.′* Here we find the ducts (*g′*) and the wood cells (*nh′*) formed as in normal wood (only shorter) but their course is horizontal instead of vertical in the plane lying at the same height as the wire. Only at some distance from the actual place of constriction upward or downward do these elements begin to pass over gradually into their normal perpendicular course (Fig. 196, *4* *g′h′*). The browned, or blackened, zone (*hp*) is not continued to *U′*.

The term "browned" or "blackened" has not been chosen without good reason, for the color from *t* to *t′* is as black as ink, from there toward *t″* a brownish black. In fact, it is ink which colors the clotted cell contents near the wire. The tannic acid of the tissue has combined with the iron of the wire and, therefore, killed the cell contents in the immediate vicinity.

This compound is diffused for considerable distances and, in fact, farther into the old wood through the medullary ray tissue than transversely through the wood cells. The fact that the wire lies directly against the old wood and has killed a zone of it should not be surprising, when we think that the constantly increasing pressure of the distending branch against the inflexible wire, leads to the compression of the soft bark and the cambium

and kills them. The dead tissue can be recognized only in small fragments along the wire.

We have already explained above how these different tissue forms are produced by the sap pressure, at first greatly increased and then nearly removed by the splitting of the bark around the wire. The almost complete breaking up of the split bark makes possible the appearance of wood parenchyma from the cambial zone; later, if sap pressure begins because of the uniting of the wound edges over the wire, thus enclosing it, true wood cells and vessels again appear but the arrangement of these elements for some time is horizontal, or spiral, diagonally ascending, caused by the strong pressure of the wire at the time when the cambial zone still lay back of it.

The extreme twisting of the wood fibres, which can be confirmed also, to a slighter extent normally, in a great many trees, and manifests itself in different degrees in individuals of the same species, is physiologically interesting. The *twisted growth* is more noticeable in dry places. The greater twisting of the wood fibres, probably caused by the bark of specimens grown in dry places which becomes inelastic sooner, is less easily split and, therefore, exercises a higher pressure.

The practical purpose of constriction is the same as that of girdling but without the danger entailed by a complete removal of considerable parts of the bark.

Branch Cuttings.

The term cutting is applied to any part cut from the parent plant, which by its reserve food materials incites various cell groups, chiefly those near the cut surface, to renewed vegetative increase so that a cicatrization tissue is formed. The separated part by forming new roots develops into an independent plant. A work by Simon[1] throws light on the anatomical conditions and the dependence of tissue differention on external factors, which appear during the pressure and can not longer be taken into consideration.

It may be asserted that an asexual propagation of this kind may be found in all classes of the vegetable kingdom and may take place from very different organs. We recall here the continued growth of torn off mycelial threads, of cut sclerotia, of isolated fruiting stems of the frondiferous mosses and of leaf and blossom parts of phanerogams. Beside the frequently occurring root cuttings, cases have also been known of the formation of roots from fruits.

We are concerned here for the present with cuttings from branches, the cut surfaces of which react to the wound stimulus by the formation of callus. In connection with this, we will then discuss propagation by root cuttings, the cicatrization of which also begins with the formation of callus. The transformation of the callus into an actual overgrowth edge by the formation of a peripheral cork zone bears very great resemblance to the formation of the overgrowth edges on girdled, or transversely cut, woody

1 Simon, S., Experimentelle Untersuchungen über die Differenzierungsvorgänge im Callusgewebe von Holzgewächsen. Leipzig 1908, Gebr. Bornträger.

branches. But in cuttings the moist medium, in which the cut surface is placed, acts as a modifier. A difference should also be determined according to whether the branch furnishing the cutting was already in a woody condition, or was still herbaceous. Instead of extensive analyses, we will give here illustrations of an herbaceous Fuchsia cutting and a woody rose cutting.

The basal part of the Fuchsia cutting (Fig. 197) is shown in longitudinal section; *s* to *s* indicates the original cut surface; the elements appearing below this line were formed after the cutting was made; above it (*s* to *s*) lie the original tissues, only one-half of which have been shown. *m* is the

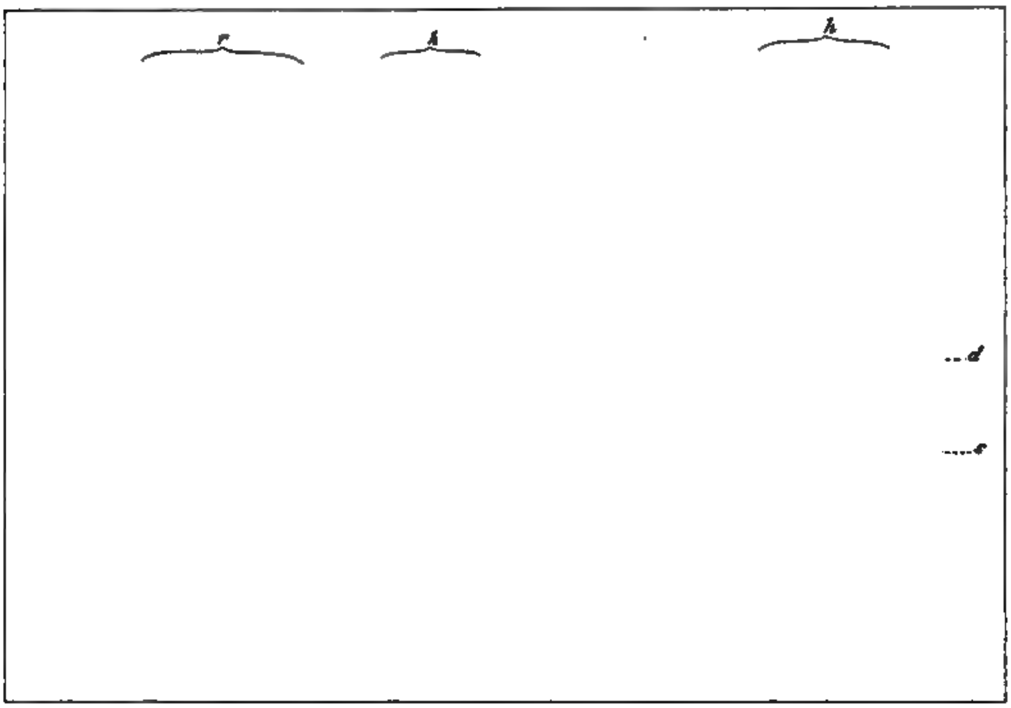


Fig. 197. Fuchsia cutting.

pith; *h*, the wood, *r*, the bark, in which extend the phloem fibres (*b*). These as well as a part of the wood cells (*h'*) have browned on the cut surface and died. The outer bark (r') also has dried up in the region of the cut surface. The younger, inner bark layers, on the contrary, and especially the pith, have healed over the wound surface by an abundant cell increase. The outer part of this cicatrization tissue is turned to cork and this cork layer (*k*) has grown to a considerable size through the activity of the cork cambium (*ke*), which forms the protection for the more tender, inner bark tissue. In the callus bark we find the broadened pouch cells (*o*), with calcium oxalate in raphides. Near these are isolated cell groups, with thicker walls (*b'*), which represent the phloem of the vascular bundles

already formed in the callus, their wood being suggested by strands of short, reticulated vessels (g''). These adjoin the vessels in the wood of the cutting, the thin-walled wood cells of which, rich in starch and bounding the pith, have participated in the formation of callus. The old wood of the cutting was torn when cut. The torn place (d) is filled with callus and the cambial zone (c to c) may be traced even into this torn place; it passes through the callus in a connected curve. The normal cambium of the cutting lay on the outer side of the wood (h). By cutting off the branch in making the cutting exactly the same change has taken place as in the ringed

Fig. 198. Rose cutting.

branch. At first uniform parenchymatous tissue was formed from the cambium, in which short, reticulated vessels (g) gradually appear. Toward the cut surface these tissue parts have become bounded by a heavy cork layer (k'), but in the outermost bark cells increase has also taken place and in the new tissue a formation of short vascular cells (g') on the outer side of which is recognizable a meristematic layer (c').

In the present example *the pith,* as well as the cambium, has been the chief centre of callus formation.

On the other hand, the pith has remained quite inactive in the case of the rose cutting (Fig. 198).

Here too *s* to *s* indicates the line of the cut; all below this is callus formation, which has pushed out the thick rolls from the original cambium and spread over the cut surface from its outer edge inward. In the longitudinal section shown in the figure, we distinguish a roll (*ca′*) cut through radially and a callus (ca^2), projecting outward from the back edge and then cut across, the bark of which has already united with the laterally incurving *ca′*. Thus, in this older rose cutting at any rate the pith is covered but this takes place by the union of edges, curving in from the periphery toward the centre, while in the Fuchsia cutting illustrated above the main mass of callus is formed by the pith itself.

The indication of the various elements agrees in general with that of the preceding drawing. *m* is the pith, which was here torn when cut. The cut (*u′*) has been filled with callus projecting out from the back edge; *h* is the old wood, formed before the branch was cut off; *nh*, the new wood formed during the period of propagation, exactly corresponding in character to the new wood of the callus in the grapevine. This begins with short, wide, porous, thick-walled cell masses, rich in starch, in which occur likewise short reticulated vessels. Their elements become narrower and narrower toward the outside and more elongated, more and more resembling the normal ones the later they are formed after the cut is made, i. e. the closer they lie to the cambial zone *cc*. This cambial zone extends around the cut surface of the old wood in broad curves and is covered on the outside by the newly formed bark (*nr*) which is not completely reproduced in the drawing. We notice on the outermost edge of the bark the corked and dying first stages of callus (*a*), extending at first over the cut surface and formed of broad, spherical to pear-shaped cells, arranged in rows, the end cells of which are rounded. These cell rows are increased at first at the ends, since the outermost cells have enlarged and been divided by cross walls, and the small end cells thus reduced in size repeat the process when growing further.

In the callus roll (ca^2), which extends from the back outward, and has been cut transversely, *g* indicates the short reticulated vessels, which represent the beginnings of the new wood. Around this extends the cambial zone (*c′*). *b* is the old phloem strand, formed before the cutting was made. It has been pressed far away from the old wood at the cut surface by the abnormal new wood formation, and has died at its free end. The cells lying against both sides of the phloem fibre groups have been released from the sap pressure by the cut and have stretched transversely (*r′*), while in a normal condition they would be elongated. The remaining outer part of the old bark (*r*) has not changed and has closed the wound with cork. *o* indicates the rhomboid, isolated crystals and stellate druses of calcium oxalate.

The new roots grow sometimes from the callus itself, sometimes from the basal regions of the cutting above the callus, according to the plant species.

THE UTILIZATION OF THE VARIOUS AXIAL ORGANS FOR CUTTINGS.

Callus formation itself as we see is, therefore, the simple process of healing a transverse wound. The formation of the cicatrization tissue at the base of the cutting is aided by especially favorable conditions. Except in healing the upper edge of the wound, the reserve substances in the cutting momentarily find no other use than in the cicatrization of the lower wound surface, since the usually shady place of propagation does not favor the bursting of the buds. Where the growing conditions given the cuttings through ignorance cause a rapid development of the buds, the formation of callus and roots is reduced or fails entirely. In the second place, the moist place of growth and the usually increased temperature of the soil act in such a way that cell increase is favored on the lower cut surface, i. e. the cicatrization tissue assumes a very luxuriant character. The formation of callus is not absolutely necessary for the cutting. Plants, which very easily produce adventitious buds, reduce their callus tissues to very small amounts. They cover their cut surface by a formation of cork and utilize their reserve substances at once for the formation and further development of new root primordia. Here an abundant cell increase occurs only in the cambial zone, lying immediately in the cut surface, whereby the base of the cutting enlarges considerably (Begonia). The formation of callus can become very injurious in trees which form adventitious roots with difficulty, since by its especially abundant development it consumes the material provided for the formation of new roots. We find, at times, enormous knotty callus swellings without any formation of roots (conifers).

The kind and age of the cutting and the vegetative conditions given it determine which tissue shall participate in the callus formation. The cambium always takes part in this. Where it does not assume exclusively the process of healing, it is assisted by the parenchyma of the inner bark, or also by a part of all of the parenchyma of the pith. Further, even the parenchyma of the wood and that of the older bark can participate in this. In herbaceous, rapidly growing plants, even in their thick-walled elements, a cell increase occurs near the cut surface because of the formation of tyloses in the vessels and of a new formation of cross walls in the collenchyma of the older bark. It has been observed here [1] that the thickened walls of the collenchyma cells and the vessels in the immediate proximity of the tyloses swell up, become porous, and are, in part, re-absorbed.

The more living parenchyma therein present, the more rapid and abundant is the callus formation. The cuttings are generally made at a node directly beneath a bud. In a cross section through a bud-cushion it is found that the parenchyma mass is greatly developed here by the passing over of the medullary connections into the bud. At the node the pith

[1] H. Crüger on Trinidad; Westindische Fragmente, XII. Einiges über die Gewebesveränderungen bei der Fortpflanzung durch Stecklinge bei Portulaca oleracaea. Bot. Zeit. 1860, p. 371.

parenchyma, as a whole, is usually living and capable of dividing, while it has died in the remaining part of the branch and is partially torn.

It should be remarked, however, that no constant rules may be given for the kind of callus formation. Often, especially in herbaceous plants, the cuttings form only very little if any callus on the wound surface, swelling out and being cut off by cork, but in another case the plants furnish considerable masses of callus. The perfectly herbaceous summer cuttings of Vitis, especially the American varieties, usually develop but little callus; sometimes, however, great masses of it. The same is true for rose cuttings, if they are cut in the early spring in a vegetative soft condition, from forced plants and stuck in a warm sand bed. A large supply of food and its slow utilization awaken a tendency to callus excrescence.

A work by J. Hanstein[1], provided with a detailed bibliography, takes up girdled cuttings. He found that such cuttings, with isolated wood and bark, which had been girdled near the base, developed roots above the girdled surface and not on the under cut surface. If cuttings, which had already formed roots, were girdled, the further development of these roots ceased and a new formation began directly above the girdled surface. An exception to this rule is found in all those plants in which fully developed vascular bundles are found or, at least, a fully developed, sieve tube system in the pith. In them despite the girdling roots are found on the under cut surface of the cutting. When stating these results, we need only add that the operation must be carried out with ripe, or nearly ripened axes in order to obtain these results. If very young herbaceous tips of woody plants are used, in which also the girdling can be done cleanly only with difficulty, the new root system is produced on the cut surface, or in its immediate vicinity. In this all the tissues with the exception of the old prosenchyma elements participate in the callus formation. The part above the girdled surface then frequently dries up. The same phenomenon may be observed if cuttings are placed upside down in the earth. Only infrequently do such cuttings grow further. After they have formed callus and even roots on the end standing in the soil, which is organically the upper end, they usually die back from above downward to a small basal part and then develop new shoots from this.

The results are of practical importance inasmuch as they clearly illustrate the transference of the plastic material, necessary for all new structure formation. We see that the main paths for the building materials should be sought in the sieve tube system in the bark. If such paths exist also in the pith, a transference of the plastic substance likewise takes place there. Besides these main paths there are also in cases of necessity side paths, which become of importance. The parenchyma cells of the bark and pith will also conduct the plastic materials upward and downward and likewise, as we see in the new formation of bark on bark wounds, the medullary ray cells in the axis can radially transport dissolved, reserve substances; but the quantity

[1] Hanstein, Johannes, Über die Leitung des Saftes durch die Rinde. Pringsheim's Jahrbücher für wissensch. Botanik, Vol. II, 1860, p. 392-467.

transported in this way is small and, therefore, insufficient for any new structures worth mentioning. The plastic substances are carried much more poorly organically upward, i. e. toward the tip, than organically downward.

As we see from cuttings set upsidedown and can perceive also from intentionally reversed grafts, under favorable conditions a transference of all fluid materials in the plants, the raw soil solutions as well as the plastic, organized constructive substances, is possible in all directions. The most easily passable paths are naturally used first; when any hindrance occurs there the side paths become of increased importance. In cuttings callus can be formed on every wounded place and this callus can produce axes containing chlorophyll and roots. Whether such a case will actually occur depends on external conditions and the typical developmental law peculiar to each plant, changed only with difficulty. Many plants form adventitious roots from the internode so rapidly that the callus formation on the cut surface has not sufficient time to make any development worth mentioning.

Contradictions in the results of the various observers are explained by the diversity of the external influences. Thus Stoll[1] states that no callus became visible with *Pogostemon Patchouli,* while Hansen[2] observed it. The former found no new vegetative points were developed from the callus tissue, while the latter could prove them, etc.

In practice it is advisable in propagating bushes not to make *cuttings* from ripened, old wood but from *succulent shoots,* which when possible are taken from plants forced in the winter in greenhouses. Under certain conditions it is advisable to make cuttings also from plants, which as a rule are propagated from seeds. It is a well known fact that cucumber and melon plants from seed of the previous year make very luxuriant foliage growth but set fruit less abundantly. Old seed with contents poor in water, however, like wilted seed potatoes and the like, behaves more favorably since the vegetative activity of the plant appears to be modified. Cuttings from the tips of vigorous shoots of cucumber and melon plants, forced in the hot bed and bearing the first fruit possibly in May, give within a few days and about this time well rooted plants with greater fertility than plants from seed.

Here, at the end of the chapter, it is necessary to call attention to the fact, that propagation by cuttings is often used for the development of new varieties. Many teratological and pathological conditions, which appear temporary in different parts of the plant, become fixed in the cutting. A great many plants with highly variegated foliage, varieties with double blossoms, etc., which originally appeared on isolated shoots, have been made permanent by cuttings. Temporary juvenile stages in Conifers varying with the place of growth are propagated further by cuttings and offered for sale as new forms or varieties. A few striking examples of this kind form

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[1] Über die Bildung des Callus bei Stecklingen. Bot. Zeit. 1874, Nos. 46 and 47.
[2] Hansen, Ad., Über Adventivbildungen. Sitzungsber. d. phys.-med. Sozietät zu Erlangen June 14, 1880.

valuable suggestions for further experiments along this line. According to Beissner[1] in order to obtain *Chamaecyparis squarrosa* from cuttings of *Biota orientalis* only the small branch axes with decussate leaves should be used, which are found close above the cotyledons. The majority of these little branches always give *Biota meldensis,* but with an evident scale-like position of the leaves, *Biota orientalis.* Likewise, cuttings of the first shoots of *Callitris quadrivalvis* give a new form. The fixed juvenile stage of *Cupressus sempervirens* may be seen in *C. Bregeoni;* the first shoots of *C. Lawsoni* give a form with squarrous leaves. *Retinospora ericoides,,* Zucc. was obtained from *Chamaecyparis sphaeroidea* var. *Andalyensis.*

The diversity of plants obtained from the ivy according to whether the cutting is taken from blind or blossoming wood is well known.

Aside from the often simpler leaf form of blossoming wood, which is easily 'transmitted to plants from cuttings, we often find their habit of growth to be more dwarfy and bushy. The subject of the retention of juvenile forms has recently been treated thoroughly by Diels[2].

Propagation by *root cuttings* is still but little used, although very advantageously in many woody plants. Paulownia, Ailanthus, Syringa, Aralia, Mespilus, Rosa, Malus may be propagated by removing larger root branches before the first growth in the spring, or before the second growth in July. These are cut into pieces possibly 5 cm. long and laid flat in rows in the soil. New plants rapidly becoming independent by their own root formation are produced at different places in the piece of root by adventitious bud formation. Among the conifers, Araucaria, Podocarpus and Gingko are said to be advantageously propagated by root cuttings especially if these are set in a warm bed. Large root stocks survive splitting lengthwise; each half then develops adventitious buds.

Some plants may also be propagated by bud cuttings (Vitis, *Paeonia arborea*). The buds are cut from the old wood in the spring just as if one were cutting long buds with some wood for grafting and these *bud cuttings* are laid flat on the surface of the soil in pots. It is advisable, however, to excite rapid growth by warming the soil.

We can also speak of tuber cuttings, since there exists a method of propagating plants by boring the eyes out of the fleshy tubers with a part of the tuber tissue containing reserve substances (potatoes, caladiums). Usually the part of the tuber, which has been cut out, forms cork on its exposed wound surface at the expense of the starch and retains the remaining reserve substances for the first nutrition of the eyes, which become independent quickly by the development of adventitious roots. The *cutting of seed potatoes* should be discussed in this connection. In practice the precaution is observed, as a rule, of not placing the pieces of tubers in the soil immediately after cutting. This precaution is perfectly justified, since,

[1] Beissner, Über Formveränderung von Koniferensämlingen. Regel's Gartenflora 1879, p. 172, cit. Bot. Jahresber. 1879, II, p. 2.

[2] Diels, L., Jugendformen und Blütenreife im Pflanzenreich. Berlin 1906, Gebr. Bornträger.

in planting freshly cut pieces, a decay easily occurs among them as soon as even a little moisture is present in heavy soils. If on the contrary the cut pieces are left a few days in the air, cork layers are formed under the cut surface, which protect the pieces of tuber. If the tubers are cut too early before sprouting, it may happen in some varieties that the pieces remain for some time in the soil apparently unchanged without any sprouting of the eyes. It is, therefore, advisable with tender varieties to spread the tubers before planting in a light, warm place until the eyes begin to enlarge and then to undertake the cutting.

The importance of the cork formation on the cut surface is shown by an experiment made by Appel[1], who supplemented the results of studies by Kny[2] and Olufsen[3]. While the two last named investigators perceived the tuber's chief protection against infection by parasites to be the wound periderm forming beneath the cut surface after a short time, Appel proves that the potato is able to protect itself before the wound cork is produced. He finds that in the most favorable cases the periderm formation sets in only on the third day after the injury and ends after two days more. Therefore, the wounded place would lie unprotected for that length of time against the demonstrably rapidly penetrating bacteria of decay if the walls of the undestroyed cells lying directly beneath the wound surface did not turn to cork immediately on the side toward that surface. In fact, this cork deposition completed after twelve hours was found in a part of the cell wall of the first and second cell layers beneath the wound surface to be entirely sufficient to prevent infection from *Bacillus phytophthorus*. The process of suberization develops less well if the pieces of tuber dry at once and are kept warm (for example, within doors). The outermost cell layers of the cut surface then dry up so quickly that the two factors necessary for the turning to cork, viz: oxygen and moisture, have only insufficient access to the tissue layers under consideration.

The closing of wounds in all fleshy parts of plants takes place in the same, or a similar manner[4].

GRAFTING.

Improving the stock by grafting consists in the artificial removal of one or more buds and their insertion in a living part of a plant for the sake of further nutrition and development. The inserted parts are usually held fast by a bandage and protected by grafting wax from the injurious effects of the atmospheric conditions. The inserted part can in general be called the *"scion,"* while the nourishing trunk is called the *"stock."* The newly produced tissue furnished in part by the stock and in part by the scion,

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1 Appel, Otto, Zur Kenntnis des Wundverschlusses bei den Kartoffeln. Ber. d. Deutsch. Bot. Ges. 1906, p. 118.

2 Kny, L., Über die Bildung des Wundperiderms am Knollen in ihrer Abhängigkeit von äusseren Einflüssen. Ber. d. Deutsch. Bot. Ges. 1899, p. 154.

3 Olufsen, Untersuchungen über Wundperidermbildung an Kartoffelknollen. Bot. Centralbl. Supplement, Vol. XV, 1903, p. 269.

4 Küster, Ernst, Pathologische Pflanzenanatomie. Jena 1903, G. Fisher, p. 185 ff.

which unites the two artifically connected members, is called the *"connecting layer,"* or, according to Göppert, "intermediary tissue." The scion is either a single bud, which has been separated, together with a part of the adjacent bark, or a piece of a twig with several buds. According to the cultural purpose the scion can be inserted at the place of its removal, or at some other place in the same individual or (most frequently) on some other individual. In the first phase, only the effect of the injury; in the latter, in addition the influence of the difference in character of the scion and the stock will have to be considered.

This process of improving the "stock" will have to be considered first of all as a process of wound healing; the favoring, or arresting influence, will have to be taken into account secondarily, due possibly to the mutual interaction of the two artificially connected plant parts.

Among the authors treating this subject thoroughly, Göppert[1] should be named first of all. He took up the subject especially through anatomical studies. A year after the publication of Göppert's well illustrated work I published a supplementary article, in part confirming it and in part correcting it[2]. Among the earlier physiologists, the statements of Hanstein[3], of de Candolle[4], of Treviranus[5] are especially worthy of consideration. Thouin[6] made a systematic compilation of all the possible variations in the process of grafting. He based his work on Duhamel[7], La Quintinye[8], Rozier[9], Cabanis[10] and the other horticultural writers and by means of abundant bibliographical citations facilitated tremendously the study of the history of the art of grafting.

Of the various forms of grafting which Thouin describes in his book under separate names and usually illustrated, only a very few have found a general acceptance. All the forms in use at present will from a pathological point of view be best arranged in their respective values, according to the degrees of injury which the stock suffers and according to the greater or lesser degree of ease with which the wounds can be healed. Under otherwise similar circumstances, the success of the manipulation will be the more certain the more rapidly the tissue of the scion forms a firm connection with the stock and, since this connection is brought about by means of the newly produced cicatrization tissue of the wound, the rapidity with which the wound is closed becomes the standard, chiefly, if not exclusively, for judging the value of the form of grafting.

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1 Göppert, Über innere Vorgänge bei dem Veredeln der Bäume und Sträucher. Kassel 1874.

2 Sorauer, Vorläufige Notiz über Veredlung. Bot. Zeit. 1875, p. 201.

3 Hanstein, Dr. J., Das Reproduktionsvermögen der Pflanzen in Bezug auf ihre Vermehrung und Veredlung. Wiegandt's Volks-und Gartenkalendar 1865, p. 190.

4 De Candolle, Physiologie végétale II.

5 Treviranus, Physiologie der Gewächse 1838, 11, p. 647.

6 Thouin, Monographie des Pfropfens. Berg's translation, 1824.

7 Duhamel, Physique des arbres 1758, II, p. 75.

8 De la Quintinye, Le parfait jardinier. Paris 1695.

9 Rozier, Cours complet d'Agriculture, Vol. V, p. 346.

10 Cabanis, Principes de la Greffe, p. 105.

The phenomena of union possible in grafting may be traced to the healing processes of three classes of wounds which I have called *bark wounds, surface wounds* and *cleft wounds.*

The injuries termed *bark wounds* (as evident from the earlier chapters) are those produced by a complete removal of the bark, so that the wood is exposed without, however, losing any of its parts. The form of grafting in which this peeling process forms the main part of the injury belongs to the type of *budding.* Here, at the time of the greatest cambial activity, the bark is raised for a certain distance from the wood of the stock and the scion (bud) is inserted into the exposed place. This scion consists of a single eye with a small bark shield (*budding with bark*), or of an eye which has been cut out with some wood from the parent branch (*budding with wood*) or of a piece of an entire twig which can be inserted in different ways and is shoved under the bark of the stock with its cut surface against the wood cylinder (*bark grafting*).

Under the term "*surface wound*" are included all the injuries in which a piece of the wood is taken away together with a complete removal of a part of the bark. The surface wound looks and behaves differently, according to whether this wound surface is produced by a longitudinal or a cross-cut. If the piece is cut from the axis longitudinally, the elements of the bark and wood are exposed lengthwise. The rain water runs off easily from this surface wound, while in a cut across the trunk it collects in little troughs and can much more easily cause the decay of the wood. A horizontal surface wound is always much more dangerous for the axis than one running vertically. On this account in general practice diagonal cuts are usually made, instead of horizontal ones.

The kinds of grafting, in which surface wounds come into play chiefly, or exclusively, belong to the type of "Copulation." The simplest form of this consists in the setting of a scion in a diagonally cut surface, produced by the cutting off of the tip from the stock where it is of the same thickness as the scion. Most nearly related to this is the single and double *saddle graft.* The scion and stock can be united also by actual longitudinal surface wounds, if the stock is cut at the side in only one place without loosening its tip. The scion either remains attached to the parent plant and, likewise, is cut only at the side (ablactation), or cut off from the branch, as in other forms of grafting, it is fitted to the stock by lateral paring. In order that the scion may fit more closely in a lateral position, its lower end is cut to a wedge and this end is forced into a cleft at the base of the surface wound of the stock. In many plants (Camelias) the scion is not infrequently cut to a short wedge and this wedge is forced into a lateral cleft in the stock, produced by a short diagonal downward cut into the wood (insertion). When the grafting fails, stock thus cut suffers least of all and after a short time can be used again.

The injury from which the trunk suffers most is the cleft wound. The form of grafting with such wounds is *cleft grafting.* This was at first used

Fig. 199. A budded rose.

generally in Germany but now only for isolated, special cases to rejuvenate older trunks. Cleft grafting consists of pushing a scion, cut wedge shaped on two sides, into a cleft in the stock which has been cut off square. This cleft is produced by splitting or by cutting out a wedge from the wood.

In considering the processes of healing, i. e. processes of union in the different forms of grafting, we must distinguish first of all whether this has been carried out on soft wood, or on branches of mature, strong wood. In the first case more tissues participate in the formation of the "layer of union" than in the latter case in which a mass of tissue is chiefly involved, formed from the cambial zone (at times also from the pith zone). This tissue forces itself into the space between the scion and the stock, or figuratively speaking must pour in between the two adjacent parts.

Oculation or Budding.

The most interesting processes of union are found in oculation. In the plate here given, a budded rose is pictured. In one-half of this drawing (from *1* to *2*), the tissue structures are shown after six days; in the other half (from *2* to *3*) after about four weeks. The section through the place of budding clearly shows the inserted bud at *E*, the stock at *w*. In the stock, ***hh*** is the old wood of the previous year, ***sh***, the wood of the current year, formed at the time of oculation. *R L* are the bark strips, raised by the T-cut; in them, *b* should indicate the phloem fibres, *t* the dead tissue of the cut edge.

At the time the bark strips were spread out from one another by the inpushing of the bud (*E*), the cambium was very active. The raising of the bark takes place here in the sapwood in such a way that the youngest vascular primordia (*g*) and the cambial layers (*c*) lying in front of them remained attached to the bark strips.

Often only the bark is raised. In fact, under some conditions, pieces of the entire cambial region with the youngest bark cells remain attached to the wood. No evidence of any fixed law has been recognized in this connection. It seems that the momentarily tenderest part is torn when the bark is raised and that individual homologous tissues can behave differently at the same time in the same varieties; in fact, that even the bark on the different sides of the trunk has a different loosening quality. Therefore, the processes of healing are unlike in the same species and variety even in the same grafted individual at different heights.

Even after 12 hours a change in the peripheral cell layers may be recognized on the edges of the wound in the bark as well as in the wood; the walls of these cells have thickened and turned yellow, either on the exposed side alone, or on all sides of the cell; the cell contents have increased. It cannot be determined whether this has taken place only because of swelling, as in the wall, or by the transference of material from the inner part of the

wood toward the periphery. The first developmental stages differ according to the life activity of the exposed cells. As a rule, all places on the exposed wood are not covered with sapwood capable of increase. If the tissue of the sapwood does not begin to increase, the cell walls on the edges of the wound swell and turn brown, together with their contents; they also collapse somewhat and form an irregular thick yellow stripe. The walls in the cell groups, which are adjusting themselves for increase, usually turn brown only slightly and frequently after a short time begin to form wound callus. The thin-walled tissue, gradually growing out in parallel rows (*ok*), is the wound tissue, the growth conditions of which were described under wounds due to barking. In Fraxinus, for example, this could be observed to be 16 cells thick after two days. The arrangement of the callus is comparatively rarely as regular as it is shown in the drawing. Because some parts of the wood do not form wound callus, the adjacent cell rows radiate from one another and cover over the places remaining inactive. This callus formation is so rapid that the covering of the inactive places and the close union of the elements coming from the different sides is a matter of course.

The bark strips on an average proceed less rapidly to the formation of wound callus. The products of the new formation are also different. To be sure, the peripheral cells, rich in cyptoplasm, project somewhat (*k*) soon after the operation, but cell increase does not always occur or, in case it does begin, its product is only cork which can protect the wound surface. The formation of new structures is more energetic and increases until an abundant wound callus tissue is formed usually first toward the inner angle, where the bark strip is firmly attached to the wood (*ok*).

The rapidly formed wound callus masses of the bark and wood, as well as ultimately those of the scion, unite and in the shortest possible time form a temporary protection for the graft wound. We say "a temporary protection" for, actually, the tissue as yet reproduced is only short-lived. As soon as the the callus tissue has acquired a considerable extent and seems exposed to increasing pressure, a meristem zone is formed in it at a certain distance from the periphery, which at times is strengthened by cork cells. The maturing of this meristem zone depends upon the distance between the stock and scion. At times, at a very short distance, only a few lateral, isolated aggregations may be recognized but when the intermediate space is great and the wound callus formation luxuriant, continuous zones may be discovered, which often after having a looped course are connected with the sharply protruding cambial zone of the older overgrowth tissue formed on the bark strips (*cc,cc*).

The meristem zone is not drawn in the young wood callus because it does not appear until later.

In common with the cambial zone of the bark strips (*cc*), this callus meristem furnishes first of all the actual connecting tissue consisting of

wood parenchyma in the form of thick-walled, isodiametric cells, or cells somewhat stretched radially, irregularly quadrangular, which appear not infrequently with somewhat bent walls (*kg*). These represent the beginnings of a wood body, which is being formed under slight pressure. By their increase they gradually compress all the thin-walled, first-formed tissue, retaining the character of phloem parenchyma (*ok*) and representing the first closing of the wound. When the meristematic zone is formed in loops, round masses of wood parenchyma are produced, enclosing the brown dead cell complexes of the original tissue. Gradually the whole tissue (*ok*) is pressed back between *1* and *2* by cells similar in character to those marked (*kg*), which store up starch.

Under favorable conditions, the scion also participates in closing the wound. In the present drawing, a bud is shown with the bark shield, but without any wood. The cut *E* is a cross section only through the bark shield. The bud belonging to this, which must be imagined in the direction (*o*), lies above the plane of the section; in this section only the large central, vascular bundle (*gb*), which extends to the bud, and a smaller one adjacent to it have been drawn. The third, smaller bundle, present in every uninjured bud cushion and likewise traversing slantingly the axis of the branch on the other side of the central bundle, has been cut away here in removing the bark shield; this does not affect the outgrowth of the bud. *On the other hand, the absence of the central vascular bundle will always signify a failure in budding.* The bark shield with the rapidly drying bud bracts can grow further without the vascular body but in my experience it has never happened that an excessively luxuriant overgrowth tissue from the bud had formed adventitious buds and in this way compensated for the dead bud.

To be sure, the formation of adventitious buds takes place in many bud grafts, as is shown in the following Fig. 200 of an herbaceous bark graft of *Aesculus rubicunda* on *Aesculus Hippocastanum,* but up to the present I have found this bud formation only on luxuriant overgrowth edges of the stock. The bark strips (*ne*) have produced such strong new structures that they have thereby been pushed out from the scion like wings. Numerous adventitious buds (*a*) stand on the edge.

In the budded rose (Fig. 199), the whole inner surface of the bark shield (*E*) has already produced new wound tissue, sometimes more, sometimes less, according to the age of the mother cells. The cambial zone of the bundle, lying below the phloem fibre groups (*b*), has formed the new cells very abundantly, as is shown by the protruding tip (*z*). The new structure on the inner side of the shield bears the character of bark tissue and is already distinguished by numerous crystals of calcium oxalate, while the cambial zone (*c*), which begins to form new wood elements, appears in later stages of the coalescence in connection with the cambial zone (*cc*) of the bark strips. As soon as this union takes place a continuous cambial ring is formed again about the whole circumference of the tree. The cambial

zone of the bud represents an integral part of this. The zone (*cc*), if traced backward, is found to be a direct prolongation of the cambial ring of the uninjured axial part.

If the wound is closed by the coalescence of the different wound tissues and the union of their cambial zones, the thin-walled tissue of the wound callus (*ok*) has almost disappeared and has been replaced by actual uniting tissue in which groups of porous cells may be often distinguished from less porous ones, as mentioned above. As indicated by the bark tip (*2-3*) the wood parenchyma, which takes over the formation of a permanent union, is also produced directly and in fact in the angles where the bark strip and wood body join, i. e. where the indicating line from *kg* ends. When it is perceived that the bark strips (*3 R L*) have been so raised by the budding knife, that not only the whole cambial zone but also the young sapwood elements already differentiated remain attached to them, then it is evident that this connecting tissue is a product of sapwood cells already somewhat older (not those most recently formed). This tissue is not produced from the wound callus (which is never formed in the inner angles) but from the division of cells already destined to be wood cells and vessels.

We have, therefore, three different factors which furnish a similar product, the wood parenchyma, already described as the uniting tissue, which takes over the process of uniting scion and stock. The first factor is the bark strip from the stock, the second the callus of the exposed wood body, the third the scion. The momentary strength of the different factors determines which one of these three actually produces the union in a growing graft or bud. The variations which may be observed are extraordinarily great. The quickest possible formation of wound callus, which takes over the temporary closing of the wound, is essential for the success of the graft. However, the union becomes permanent only if the cambial zone (*cc*) of the strips (*R L*) which forms the new wood and which I have occasionally called *"the mobile wound-wall"* occurs in permanent union with the cambial zone (*c*) of the scion (or bud) and forms wood elements remaining in a connected layer. The mobile wound-wall shows the character of the usual overgrowth edge by its cambial zone which is spirally twisted on the free side, and distinguished from this overgrowth edge, the *"fixed wound-wall,"* by the large, inpushed zone of wood parenchyma (*kg*), which passes out from the fixed wound-wall. The point of union of the cambial zones of stock and scion (or bud) is recognizable not only in the year of the union but remains so for many years, by the course of the wood elements. In the line of union, which extends from *c* to *cc*, the elements are more or less strongly elongated tangentially, while in the interior of the wound-wall they have already assumed the normal vertical arrangement and, therefore, in cross section appear actually cut across (*hh'*), thus resembling the normal wood (*hh*). If, in the production of this uniting tissue, the cambial zone (*c*) of the scion (or bud) unites with that of the stock (*cc*) to form a continuous ring, it is evident that this ring is not everywhere

equally distant from the centre as in an ungrafted or unbudded trunk, but at *z* and *cc* shows a deep depression, an S-like curvature. This curved line of union, *Göppert's "line of demarcation,"* is visible to the naked eye and is noticeable even in the bark covering[1].

In the second, usual method of budding "with a heel," the bud is *cut from the branch with a little piece of wood attached* and is shoved into the stock. In this the processes of healing vary somewhat from those described above. The disadvantage in this method is a retarding of the union; the advantage, however, lies in the increased certainty of preserving the bud. In separating the bark shield from the wood body, for the purpose of bark budding, the actual bud cone is not infrequently left on the branch if its vascular bundle cylinder has been too greatly lignified. The bud on the bark shield then has a hole on its underside and does not sprout. Untrained workers overlook this little hole and bud in vain.

The same process of healing, as in budding with a heel, is found in *bark grafting.* Only in this case the stock is more injured since it must first be cut square off, then the bark on one side is split and somewhat raised for the insertion of the scion as is done in budding. Instead of the single eye a diagonally cut branch is used, bearing several buds. The slanting cut surface forms simple overgrowth edges, i. e. fixed wound-walls, which unite with the mobile wound-walls of the bark strips of the stock and the uniting tissue of its exposed wood surface. In bark grafting (*"whip grafting"*), however, the stock has more to do and stores up less reserve plastic material, since the part of the cross section on the end surface of the stock not covered by the scion must also be overgrown.

Fig. 200. Bark graft of Aesculus, with adventitious buds.

The luxuriance, to which the process of coalescence can attain in bark grafting on strong stock, is shown by the accompanying drawing (Fig. 200),

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[1] The difference between the present experiments and previous work lies in the proof of the different origin of the tissue of union or, according to Göppert, the "intermediary cell tissue." He thinks that the production of the tissue which, in common with the cambium, takes over the coalescence, must come from the medullary rays, while Hanstein considers the whole tissue of union to be produced by the cambium alone. Actually, all elements, still capable of new formation, can take part in the formation of the wound callus and tissue of union. In many trees, for example, good instances of wound callus may be obtained which is formed from the pith body, particularly the pith crown. (Tilia.)

of the grafting of *Aesculus rubicunda* on *Aesculus Hippocastanum*, taken from nature. A few weeks after the grafting the new structures on the inner side of the bark strips (*nl*) of the stock had become so extensive that they stood out like wings from the scion and produced adventitious buds (*a*) on the cut surface.

Copulation and Grafting.

In copulation, the lower end of the scion and the upper end of the stock are cut slanting, and, when possible, both are of the same size. The two cut surfaces are so fitted to one another that the respective tissues of both coincide. Thus we have here simply two surface wounds. These form complete overgrowth edges which push in between the scion and stock. When the manipulation is well carried out and the space between the wound surfaces very small, the closing of the wound is so perfect that even the microscope can show no spaces between the old wood of the cut surfaces and the compressed connecting tissue. Göppert finds that, in copulation, this connecting tissue dies in a young condition without disappearing, while in grafting, when the union is complete, it remains for a long time organically active. In my experience, no such difference dependent upon the method used has appeared in the length of life of the connecting tissue. In older cases, holes may indeed be noticed, or brown, decayed masses of dead tissue. It seems to me, however, that this would occur in all grafting without any distinction as to method used, if the wound by very careful adjustment of stock and scion has been closed by the wound callus first produced without any subsequent formation of woody parenchymatous connective tissue in the union. Copulation may, therefore, retain the value and the universal application which it has had up to the present. However, I consider the simplest form to be the best and the so-called English grafting, as well as Thouin's methods (Miller, Küffner, Ferrari, etc.) disadvantageous or even injurious and trifling.

Cleft grafting may be considered as the most dangerous operation. The stock is usually cut off square and split once, or several times, deep into the wood. The scion is cut wedge shape and so clamped in the cleft that its cambial zone forms the connection between the two parts of the cambial ring of the stock separated by the cleft. In case the wedge-shaped scion is not herbaceous, it will on both sides produce wound walls from the remaining part of its cambium alone. This occurs also on the split edges of the stock. The united connecting masses will endeavor to fill out the space in the old wood. On an average, this succeeds very rarely; in spite of the grafting wax, moisture penetrates into the split from the square cut surface of the stock and easily causes decay or allows some fungus to enter.

The process of grafting naturally does not depend upon the existence of a definite cambial zone but will be possible also in monocotyledons. Daniel[1] gives an example of this; he carried out grafting experiments successfully with Vanilla and Philodendron.

[1] Daniel, L., Greffe de quelques Monocotyledones sur elles-mêmes. Compt. rend. 1899, II, p. 654.

In concluding this consideration of the healing processes of wounds, it should be emphasized once more that the decision as to the relative value of the grafting method used refers here only to axes at least one year old and already provided with well developed wood. In grafting the soft wood of woody plants, or herbaceous plants, the choice of method may be governed by purely practical considerations. In the coalescence usually so many elements of the cut surfaces (older bark and wood elements in pith) participate in the formation of wound callus that a close union takes place under all circumstances favorable for the plant body, provided, of course, that a sufficient relationship exists between scion and stock.

The Longevity of Grafted or Budded Individuals.

It cannot be denied that, aside from the possible action of different peculiarities of the two grafted parts on one another, grafting influences the development of the individual. As Duhamel has already emphasized, the tissue changes at the place grafted will at any rate cause a change in the conductive capacity. The connecting layer will produce retardation of the water conduction and an easier storing up of the descending, plastic materials in the part which consists of wood parenchyma, rich in starch, as also later when the connecting layer is formed from interwoven prosenchyma elements. The results of these changes have already been discussed.

The limit, up to which different individuals can be united with one another to form a persistent, normally functioning organism, as yet little understood, may be determined by the fact that, in general, only plants of the same natural families can be grafted (or budded) upon one another with any prospect of success. According to all previous experience, this would, however, represent the extreme limit. A sufficient number of examples are known of cases where members of the same family cannot be united permanently. In fact, varieties of the same family can remain united for a few years and then in the end break the union, in which case, as a rule, one part dies. It is probable that, aside from the material relationship, a similar biological development is absolutely necessary in the two individuals which are to unite. I, therefore, believe that the different beginning and end of the vegetative phases (leaf formation, setting of fruit, etc.) and the different amounts of water needed by the individuals is very decisive for the permanence of even those unions which were successful in the beginning. Often such cases of grafting remain fresh for many months without any firm union. In herbaceous grafting of heterogeneous varieties, or organs, it is found that the scion often continues growth and develops a sickly inflorescence but finally dies. So far as I have had insight into this matter, no union had taken place. Both parts may have done their best; all their tissues, capable of developing further, can produce new structures and even, in places, a nominal wound callus but a brown stripe extends between the tissue masses of both parts, which shows at once to which individual the tissue in question belongs. The brown stripe is either formed

of the swollen walls of the outermost cells, or caused by the collapse of all the cells of the wound edges. Usually on the boundary a cork layer has been formed by the suberization of the walls of the peripheral parenchyma cells or, besides this, by the appearance of actual cork cells.

In genera which finally unite, as, for example, Iresine on Alternanthera, it is found that for whole stretches of the grafted surfaces, the connecting tissues grow side by side, cut off from each other by a cork layer.

Similar cases may be proved in *root grafts* (*Bignonia*) and it could be observed in cleft grafts of *Paeonia arborea* on fleshy roots of *Paeonia officinalis* that the root, as stock, had served only as a receptacle for the scion. This latter had formed roots without any union with the stock.

Root grafting is in general a very good method. Even for our *fruit trees* it had been used by Sickler at the end of the seventeenth (?) century and later Seigerschmidt in Mako recommended it very highly[1]. Root pieces, varying in thickness from the size of a quill to that of one's thumb, seemed suitable, if provided with fine roots. They were cut in pieces eight to twelve cm. long, were grafted by copulation or cleft grafted and the place of union covered with earth until only two or three eyes extended above the soil. Trunks of old seed- or stone-fruits give an abundant material for stock, when they have to be removed. Of course, the roots must be very healthy. The method of grafting roses on pieces of roots in January or February has been adopted already. For Clematis and other woody plants, this method of grafting is becoming more and more of a favorite.

It may be presumed from the very beginning that under certain circumstances which condition a scanty coalescence, the *life period* of a graft will be very short. The question, whether the process of grafting in itself limits the life period, as Thouin and Göppert have stated, must be laid aside. It cannot be denied that grafted fruit trees, on an average, are shorter lived than those grown on their own roots. It may even be granted that a dying of the trees, as Göppert has observed, is initiated in the line of demarcation by a gradual rotting of the place of union but it is not credible that this process of rotting may be the cause of actual death, or even of disease, in grafted trees. It is found, on the contrary, that even badly united copulants, which at first may have been simply stuck together on one side, can in the end give perfectly healthy permanent trunks. The old places of union have the firmest wood. A storm may twist the trees off more easily at any other place than at that of the union. Göppert's observations may possibly hold as the rule only in old trunks which have been regrafted later. I would explain the comparatively earlier death of grafted trunks by the fact that not only better but also more tender cultural varieties are used for grafting. These, aside from the disturbances which they undergo in the cutting, are in themselves more susceptible to disturbances in growth and to unfavorable weather than the specimens grown from the seed, which approach more or less the hardier nature of the stock.

[1] Weiner Obst- und Gartenzeitung 1876, p. 587.

Mutual Influence of Scion and Stock.

In regard to the influence of the stock on the scion, the experience of practical growers has shown for some time that apples set on Paradise stock retain a lower habit of growth and at times bear fruit even in the first year after grafting. In the Doucin the forms become larger and fertility begins after a few years, while the scion, on a stock of *Pirus Malus,* attains the usual tree form and bears fruit only after a considerable number of years. For pears, the quince and Crataegus, which love moist soils, form the best dwarf stock. For exposed or dry positions, *Pirus Malus prunifolia major,* together with *P. M. baccata cerasiformis,* the cherry apple, have been recommended from several localities as stock for apples[1]. *P. M. prunifolia,* originating in Siberia, is hardy and may be used as a street tree. It differs from the variety of *P. M. baccata* by its conspicuous, retained calyx. With the variety of *P. M. baccata* belongs also *P. M. cerasiformis,* which drops its calyx at the time of ripening.

Lindemuth states, in regard to the life period of tree trunks, that varieties grafted on Paradise stock seldom live more than 15 to 20 years, while specimens grafted on seedlings of true tree varieties of Malus can become 150 to 200 years old. Of the remaining literature, we will mention the following examples:

Sour cherries grafted on sweet cherries thrive less well than sweet varieties on sour ones[2]. Oberdieck found that sweet cherries bore abundantly on sour cherries.

Treviranus[3] quotes that walnut and chestnut trees of the late sprouting varieties are said never to succeed on early sprouting varieties (according to Cabanis, *Traité de la greffe*). On the other hand, in seed fruits, this method of grafting later varieties on early ones is said to have good results and to bring about an earlier ripening of the fruit[4]. In peaches, grafting in itself, whether of early varieties on late varieties, or conversely, seems to give good results. Gauthier reported to the Parisian Société cent. d' Horticulture[5] that he had grafted peaches in August or September on typical fruit spurs (*coursonnes*), as well as on those which have elongated, both late varieties on early varieties, and conversely. The fruits are said to become larger because, in the tree which is grafted with a late ripening variety, the fruit of the stock can be harvested first and then the tree can use its remaining strength to mature the fruit on the branches of the grafted, late variety. In the opposite cases, of grafting on late varieties, the whole tree becomes stronger because late varieties in general have a more luxuriant habit of growth.

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1 Lieb, **Pyrus Malus prunifolia major.** Pomolog. Monatshefte 1879, p. 130.

2 Lindemuth, Vegetative Bastarderzeugung durch Impfung. Landwirtsch. Jahrbücher 1878, Part 6.

3 Treviranus, Physiologie der Gewächse II, 1838, p. 648 ff.

4 v. Ehrenfels, Über die Krankheiten und Verletzungen der Frucht- und Gartenbäume. Breslau 1795, p. 108.

5 Ortgies, Vorteilhaftes Pfropfen von Pfirsichbäumen. Pomolog. Monatshefte v. Lucas 1879, p. 61.

An older example from Duhamel[1] should be mentioned in this connection. Almonds grafted on plums and, conversely, plums on almonds, at first grow very well but usually retrogress after one or several years. The almond has a much more luxuriant habit of growth, sprouts earlier in the year and, as scion, forms a strong roll at the place of grafting. It is probable, therefore, that such a scion, requiring more water earlier and constantly, will thrive on a less luxuriant stock as long as this is able to satisfy the young twigs from its reserve store in the trunk. If the grafted branch becomes several years old, its needs become greater and, if it cannot accommodate itself to the stock, as frequently occurs (dwarf trees of seed fruits), it gradually degenerates from a lack of nutriment. The results vary greatly, according to soil, amount of water and variety. Conversely, a stock which blossoms too early and *grows too luxuriantly* will supply more to a scion, requiring a lesser amount, than this can take up. The superfluous material from the stock is quickly worked over into new structures. If many groups of buds are present, this excess manifests itself in the production of long shoots. If, however, as in grafting, most of the lateral buds, or eyes, are suppressed, the material remains at the disposal of the thickening ring of the trunk. Thus, instead of prosenchymatous elements, aggregations of wood parenchyma are formed, which, in the Amygdalaceae, easily become gum centres as I also have observed. Among the older observers, Duhamel reports that almond stock, grafted with plum scions, will die from gummosis at the place of grafting.

Experience has also taught, in the very general practice of grafting pears on quince or apples on Paradise stock, that death sets in the more quickly for rapid growing scions, the drier the soil and the fewer the roots which the stock has developed in it. The scions fail much the more rapidly. Duhamel also cites cases when, under such disproportionate need of water in scion and stock, even ***simple transplanting has led to death through failure of union*** (almonds on plum stock), while the little trees of the same series, left standing in the nurseries, remain healthy. The pruning of the roots in transplanting has decreased too greatly the momentary capacity of water absorption in the stock. Peaches on prune stock are also said to give no especially permanent union[2]. The wood of the scion is said to turn red and soon degenerate. I would add here an experiment with the grafting of raspberries on *Rosa canina*[3]. Among rubus scions grafted by copulation, I found two branches developing on one specimen, one of which bore four normal raspberries. In the autumn, however, the scion died and, upon investigation, the coalescence was found to have been very slight. On the upper part of the surface of copulation, only the stock had developed cicatrization tissue. On the other hand, on the lower part of Rosa, as on Rubus, abundant wound callus had been formed, showing normal processes of coalescence.

1 Duhamel du Monceau, La physique des arbres 1758, II, p. 89.
2 Pomolog. Monatshefte 1879, p. 370.
3 Sorauer, P. Rubus auf Rosa. Zeitschr. f. Pflanzenkrankh. 1898, p. 227.

Evergreen foliage seems to be no hindrance to growth on deciduous stock. Scions of *Prunus laurocerasus* on *Pr. Padus,* of *Quercus Ilex* and *Q. Suber* on *Q. sessiliflora,* of *Cedrus Libani* on *Larix europaea* are said to thrive but there is no report as yet as to a favorable growth of deciduous wood on evergreen stock. Thouin contradicts the former statement[1].

Of the noteworthy results of Duhamel's experiments, it should be mentioned here that, for example, the fruit of the winter Christ pear on quince had a more delicate, juicier flesh and a finer, deeper colored skin, as contrasted with scions grafted on wild stock. Leclerc du Sablon[2] observed that pears grafted on pears store up less reserve substances in their aërial parts than when grafted on quince stock, while the roots are poorer in reserve substances. This latter fact might be explained by the greater fertility after grafting on quince stock.

It is remarkable that pears and apples, which form so perfect a union with remotely related stock, can never, or rarely ever, be brought to form a permanent union with each other. Numerous experiments have been made in this connection. Thus Knight[3] reports a case of apple on pear stock, which for one year yielded an abundant harvest but died the following winter. The fruit is said to have had blackened cores, not containing a single seed. Recent observers have affirmed this fact in general, but emphasize the fact that exceptions may occur. Thus Stoll[4] reports that apple scions took well on pear trees and bore very soon but the fruit was small and the graft usually died in the fourth year. The head gardener, Seifert, in Segeberg (Holstein) describes a five year old apple graft on pear stock which in the fourth year had borne six well developed apples (Ribston Pippin). The apples had a good flavor but the crown of the tree had a weak growth. I have known of some favorable results from pear grafts on apples. In Czerwentzitz, near Ratibor, many examples were found of pears which had been grafted on apples. The method was in use at least ten years ago. In the first experiment (Geisshirten pear on apple) it was found that after the second year the fruit from pears on apple stock ripened two weeks earlier than on the main trunk. The scion lived eight years. Less vigorous stock gave no good results. Most varieties, to be sure, remained alive but made no growth. When the same grafting was repeated on the middle branches of the crown, a number of specimens died after two or three years. The others lived in a weak condition for some time without setting fruit. A note by Gillemot[5] originates from this period. He had two-year-old pear grafts on apple stock and also had grafted cherry scions (Royal Amarelle) in the bark of a plum (*Prunia institita*). The scions developed very long

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[1] Thouin, Monographie des Pfropfens. Berg's translation, 1824, p. 114.

[2] Leclerc du Sablon, Sur l'influence du sujet sur le greffon. Compt. rend. 1903, CXXXV. p. 623.

[3] Hort. Transact. II, p. 201.

[4] Stoll, Das Veredeln von Birnen auf Äpfeln. Wiener Obst- und Gartenzeit. 1876, p. 10.

[5] Gillemot, Beitrag zur Veredlung verschiedenartiger Gewächse aufeinander. Wiener Obst- u. Gartenzeit. 1876, p. 121.

shoots and bore comparatively many and handsome fruits in the second year but died after bearing.

Up to the present, such experiments have been repeated on all sides but as yet no further desirable results have been attained than those known for a long time in regard to the use of dwarf stock. In some cases it was evident that the manner of grafting decided the success. Thus, for example, Carriére[1] reports that the varieties of pears *Bon chrétien Rans, Doyenné de Juillet, Beurré Gifford, Beurré Box.* did not grow, or died soon after producing weak shoots, if they were budded on quince (*greffé en écusson*). On the other hand, the results are considerably more favorable, if cleft-grafting is adopted and branch tips used as scions. The fertility is unusually great. *Ligustrum ovalifolium as stock* is also said to behave differently with different varieties of lilac. Only *Syringa Josikea* is said to succeed when budded (*greffé en écussion*) while *Syringa Emadi persica* and others develop well only when cleft grafted (*greffé en fente*).

Recently special attention has been given this question in *the grafting of grapes* because of the struggle against the grape louse. The number of works on this subject is very great, so that we call attention only to a few important ones. First of all Couderc[2] determined, by questioning about 450 French grape growers, that even the power of resistance of an American stock to the attack of the grape louse is usually somewhat reduced by grafting and also that the different varieties used as scions exercise an influence varying in intensity.

Cases occur, however, in which a very vigorous scion can increase the power of resistance. Ravaz[3], among others, lays especial emphasis on the fact that the stock influences the growth of the scion and also its fertility. We owe to Hotter[4] precise figures on the changes in grapes, due to the influence of the stock. He investigated different varieties of grapes grown on vines grafted on Riparia and on self roots of vines of the same varieties. Among 9 varieties, 77 per cent. of the juice from the grafted vines contained more acid than that from the non-grafted vines, of which 65 per cent. contained more sugar than those grafted on American stock. These statements are directly opposite to those of Curtel[5], who found the fruit of grafted vines larger, the skin thinner and the seeds less numerous but larger. The juice was richer in sugar than acid, poorer in ash elements, especially phosphates, richer in nitrogenous elements but poorer in tannin. We have purposely cited both observations in order to show how differently the stock

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1 Carrière, Quelques observations à propos de la greffe. Revue hort. 1876, II, p. 208.

2 From the Weinbau-Kongress of the 16th to 19th of August, 1894 in Lyon; cit. Zeitschr. f. Pflanzenkrankh. 1895, p. 118.

3 Ravaz, L., Choix des porte-greffes. Revue de viticulture 1895, Nos. 100, 105, 106.

4 Hotter, E., Der Einfluss der amerikanischen Unterlagsreben auf die Qualität des Weines; cit. Centralbl. f. Agrikulturchemie 1905, p. 625.

5 Curtel, G., De l'influence de la greffe sur la composition du raisin. Compt. rend. 1904. Vol. CXXXIX, p. 491.

can act. We find further experiences reported in the Memoirs of the Imperial Department of Health in Berlin.

Thus, for example, the twenty-fifth Memoir confirms the above mentioned observation that the American vine, when grafted, loses in power of resistance to the grape louse, jaundice, etc[1].

In regard to the technic which has come into use in grafting grapes, we will follow Schmitthenner's[2] statements. He emphasizes the fact that, at present, the so-called *English tongue grafting* is almost universally used. This is a form of splice grafting in which the diagonal cut is not long but the cut surface of graft and stock have also an axial incision. The scion is split and shoved into the cleft of the stock so that scion and stock dovetail. Anatomical investigation shows that in grafting grapes the activity of the cambium is more reduced than in any other form of grafting; the annual ring formed after grafting is much weaker than the normal one. The influence of the wound is much more considerable than in grafting other woody plants and extends even to the next node, since all the ducts are filled with corky tyloses containing wound gum.

Tompa[3] had already given detailed anatomical data on grafting grapes in a herbaceous condition. However, the grafting of grapes will be completely effective only if one uses as stock, not the American varieties, but hybrids of those which are adapted to the various localities[4].

Since the end of the last century, the *formation of hybrids by grafting* has been better understood. The best known example is *Cytisus Adami* which is said to have come from the grafting of *Cytisus purpureus* on *Laburnum vulgare* and, at times since 1826, has produced on different branches sometimes the blossoms of one variety, sometimes those of the other. According to A. Braun[5] the retrogression did not appear until sixteen years after the grafting. Laubert[6] found that retrogressive formation should be ascribed to a bud variation, in which the branch form, representing *Cytisus purpureus,* also completely resembles anatomically the true variety. Beijerinck[7] found that this bud variation could be incited often by wound stimulus.

The description of a different example was published in 1875[8]. In an English grape house, a vine which had been grafted with *Black Alicante* was re-grafted some time later with three varieties on the *Black Alicante* as

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[1] Funfundzwanzigste Denkschrift betreffend die Bekämpfung der Reblauskrankheit. Bearbeitet im Kaiserl. Gesundheitsamte bis October 1, 1903.

[2] Schmitthenner, F., Verwachsungserscheinungen an Ampelopsis- und Vitis-Veredlungen. Internat. phytopath. Dienst. 1908, No. 1.

[3] Tompa, A., Soudure de la greffe herbacée de la vigne. Annal Instit. ampélologique hongrois 1900, Vol. I, No. 1.

[4] Teleki, Andor, Die Rekonstruktion der Weingärten usw. Wien und Leipzig, Hartlebens Verlag, 1907.

[5] Bot. Jahresber. 1873, p. 537.

[6] Laubert, R., Anatomische und morphologische Studien am Bastard **Laburnum Adami.** Poir. Bot. Centralbl. Supplementary Volume X, Part 3.

[7] Beijerinck, M. W., Beobachtungen über die Entstehung von **Cytisus purpureus** aus **Cystisus Adami.** Ber. d. Deutsch. Bot. Ges. 1908, Part 2, p. 137.

[8] Grieve, Culford, Bury St. Edmunds, Singular Sport of a Grape Vine. Gard. Chron. 1875, p. 21.

stock. One of these three varieties, together with a small piece of its stock, was cut off later. Immediately a sprout, standing near the centre of the branch of the second inserted variety (Trebbiano) showed a spur with grapes which resembled absolutely the variety (Golden Champion) which had been removed. On either side of this abnormal spur, the Trebbiano stock bore its characteristic fruit. Therefore, no other hypothesis remains possible than that the Champion variety, which had been removed, had exercised an influence backward into the stock (*Black Alicante*) and through this to the laterally grafted Trebbiano variety.

Lackner has cited another remarkable and older case[1]. He found in the garden Palavicini near Genoa, under the name *Maravilla di Spana,* an orange (*Bigardia bizarro* Riss.) which, on parts of its outer surface, showed callus excrescences and corresponding ones in the flesh, resembling in places a lemon, in others an orange and sometimes candied lemon peel. It has been proved that this form originated about 1640 when a gardener in Florence grafted some stock but the scion did not take. Directly beneath the place grafted, however, a branch appeared which bore this very remarkable fruit. The blossoms are likewise different, some being white, others red.

In 1873 the "Revue horticole" published a case in which a Mr. Zen had bred new rose varieties by grafting. These varieties remained true.

Focke[2] mentions a white moss rose which had been grafted on a red Centifolia. Such a plant developed bottom shoots which bore some white moss roses, some Centifolia and also moss roses with partly red petals. Besides the roses here described, Pirus, Begonia, Oxyria and Abies have also been named as genera in which graft hybrids can occur.

Daniels found a backward action of the scion on the stock in one instance in which old pears, grafted on quince, had been sawed off 2 m. above the surface of the soil. Branches developed from these naked stumps, some bearing normal quince leaves, others mixed forms, between quince and pear[3]. This same author, in collaboration with Jurie, cites similar instances in grafted grapes. Of these, however, Ravaz[4] has proved that such variations also occur in non-grafted vines. Such cases of interchange occur often; there is always a tendency to trace formal differences back to the special influence of the grafting, which, in fact, are only variations in luxuriant branches. Such variations appear also after severe pruning of the older axes. We need recall only the manifold leaf forms on the bottom shoots of Morus, Populus, etc., after the trunks have been sawed off.

The majority of errors occur in grafting experiments on herbaceous plants. For this we have also examples by Daniel[5], who grafted turnip

[1] Lackner, Einfluss des Edelreises auf die Unterlage bei Orangen. Monatsschrift d. Ver. z. Bef. des Gartenbaues v. Wittmark 1878, p. 54.

[2] Focke, Die Pflanzen-Mischlinge. Ein Beitrag zu Biologie der Gewächse. Bot. Centralbl. 1880, p. 1428.

[3] Daniel L. Un nouvel de la greffe. Compt. rend, 1903, Vol. XXXVII.

[4] Ravaz, L., Sur les variations de la vigne greffée; response à M. L. Daniel. Montpellier 1904.

[5] Daniel L., Creation des variétés nouvelles au moyen de la greffe. Compt. rend. 1894, I, p. 992.

rooted cabbages on Alliaria and this on the green cabbage. He found morphological and anatomical differences in the plants produced from the seed of the grafted specimens. Under this head belong also potato grafting experiments and the grafting of *Solanum Lycopersicum* on potatoes. In regard to the grafting of various Solanaceae on each other there exist very many experiments which we have described more fully in the second edition of this manual (cf., p. 692 ff). The most thorough experiments, continued up to the present time, are those by Lindemuth, whose investigations have been considered under the section on Albinism (cf., p. 677 ff). Molisch[1] has repeated earlier experiments and, agreeing with Strasburger and Vöchting, has arrived at the conclusion that the production of graft hybrids may well be explained theoretically but has not actually been satisfactorily proven since, as he says, he and the others had found that scion and stock always retain their morphological character.

We are not able to share this point of view since Lindemuth's[2] latest experiments, as well as those of E. Baur, sufficiently demonstrate the influence of the scion on the stock. Nevertheless, bud variations in many cases are also found which have nothing to do with the material influence of the scion on the stock but are probably traceable to wound stimulus. Arrestment phenomena of very different kinds, as, for example, increased pressure in the bud, can initiate a different development of the young axis.

The influence of the stock on the scion is a well known fact in horticulture. We will recall only the different effect of the stock on one and the same apple variety. Grafted on Doucin, a stronger wood growth and a later fertility was produced, on Paradise stock a lesser wood growth and an earlier setting of fruit. No general rule may be laid down. The result depends not only on the plant variety but also on the accessory conditions (age, habitat, form of nutrition, etc.).

The Natural Processes of Coalescence.

Very frequently we find in hedges *the union of two branches,* which oftentimes have grown toward each other from opposite directions. The same phenomenon may be observed in *roots* in dense tracts of trees.

The root fusions can take place in a young stage of the organ at a time when the epidermis is still capable of division. According to Franke[3] this process appears in the ivy (*Hedera Helix*) and the wax flower (*Hoya carnosa*), in both of which plants the epidermal cells of two adjacent roots grow toward each other like papillae and unite. These cells then divide and thereby produce a few layers of connecting tissue. This, however, does not have the firmness of the connecting tissue produced from the cambial zone

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1 Molisch, H., Über Pfropfungen. Lotos 1896; cit. Bot. Jahresber. 1897, I, p. 155.
2 Lindemuth, H., Kitaibelia vitifolia Willd. mit goldgelb marmorierten Blättern. Gartenflora 1889, p. 431. Über Veredlungsversuche mit Malvaceen. Ibid. 1901, No. 1.
3 Franke, Beiträge z. Kenntnis der Wurzelverwachsungen. Beiträge z. Biologie der Pflanzen von F. Cohn, Vol. III, Part 3; cit. Bot. Centralbl. 1882. Vol. X, No. 11, p. 401.

in two bark-covered roots of older, woody plants. The same process sets in here as in the union of aërial organs. The bark on the surfaces of contact is sometimes pushed toward the outside, sometimes enclosed like little islands; the cambium no longer increases where the pressure makes itself felt on the places of contact, but unites from a common layer, enclosing both roots. Each year, when properly nourished, this layer forms new wood layers above the place of union.

In regard to the anatomical conditions in the coalescence of tree trunks, we will refer to Küster's different works[1] and will mention here only one rare case which we have observed personally. This was found in the Ellguther forest, near Proskau, in a pine; at several places on its trunk a second, thinner trunk had grown fast by natural in-arching.

The base of the weaker tree had been cut off many years before so that the trunk was obliged to draw its nourishment entirely from the older pine. At the time observed, they were perfectly healthy, and formed a common crown; only it seemed to me that the in-arched, rootless trunk bore somewhat shorter needles.

I possess a piece of the trunk of another pine in which the tip of a branch, possibly five cm. in diameter, had bored into the main axis and there disappeared entirely. This is an example of so-called "*handled trees.*"

Fig. 201. Pine from the Ellguther forest in which one trunk has continued to nourish a second, rootless one connected by natural grafting.

All processes of this kind arise from the ability of the cambial tissue to form connecting layers between different axes. The processes differ from grafting only in the previous separation of the cambial layers by the bark of the plant parts; these layers

[1] Küster, E., Über Stammverwachsungen. Jahrb. f. wiss. Bot. Vol. XXXIII, Part 3.—Pathologische Pflanzenanatomie. Jena 1903, Gustav Fischer, p. 173, Section Wound Wood.

unite later. The bark must have been removed by gradual rubbing. If the union of the axes takes place of itself, a connected wood covering is deposited each year over the place of union. Often rather larger brown pieces of dead bark are incorporated in the surface of the union. This may be explained by the uneven formation of the two axes which have come in contact. If two trunks, covered with bark scales, touch each other, the most prominent places are rubbed down first and unite, while more deeply lying hollows do not participate in the union but are enclosed by the new tissue.

In forests and especially spruce and pine tracts, *twin trunks* are frequently met with, which, beginning at the base, had united for different distances. Less frequent are the cases in which the upper parts of the main axes of separate origin have grown together.

A cross section of the base of a twin trunk often shows three centres. In conifers, the middle, third stem has, as a rule, become very resinous. At any rate, the top of the main axis was broken off when young and two lateral eyes have taken over the growth. Instead of forming horizontal branches, these have developed into two top shoots which, after a considerable number of years, have suppressed the dying main axis and finally overgrown it. Their overgrowth edges have gradually united so that, finally, one single, united cylinder has come from the three axes.

According to the experiments mentioned under grafting, it may be assumed as a definite fact that a union can take place between parts of individuals of different kinds. Spruces and firs, apples and pears, with each other and on quinces, or almonds and plums, and the like, may serve as examples well known to all. Nevertheless, a limit in the relationship of the plants certainly exists here, beyond which actual coalescence cannot take place in spite of the closest contact and vigorous rubbing. To be sure, a whole list of reports on the union of very heterogeneous plants may be found in the literature on this subject but a part of these statements is based certainly upon erroneous observations[1] in which union was assumed where only *overgrowth took place.*

Having so fully described the processes of wound healing, we may here, without being misunderstood, express the opinion that the apparently rigid wood body of a tree may be caused to take on all imaginable forms if the tissue produced from the cambium is confined in some way. It can be said figuratively that the wood trunk flows about any object standing permanently in the way of its growth in thickness; it grows over it and can enclose it entirely. Examples of so-called *encysted stones, fir cones and even animal mummies* have frequently been observed.

We can here omit the enumeration of special cases, since we now possess a number of most interesting books about remarkable trees and all

[1] Moquin Tandon, Pflanzen-Teratologie, Schauer's translation, 1842, p. 274. Masters, Vegetable Teratology 1869, p. 55.

kinds of botanical nature curiosities. The one by Ludwig Klein[1] may be the most instructive at present. This seems especially fitted to arouse and increase a love of trees by its more than 200 illustrations, made from photographic exposures.

Wound Protection.

We have already partially discussed natural wound protection in so far as it is produced by cork formation. In the wood body of trees, however, no cork deposit is found rapidly covering the surface of the wound, but the vessels in all such places are filled with tyloses or a gummy substance (*wound gum*) usually easily soluble in boiling nitric acid (dissolved with difficulty in the Correae). This is found when healthy wood adjoins the dead wood. As a rule, the tyloses are accompanied by some gum formation. Both kinds of filling make the wood of the branch stump absolutely impervious to water and air and quickly close the wound within the period of growth. It is evident from this observation that we would do well to thin our trees in winter shortly before cambial activity begins[2].

In a great number of woody plants, the vessels and frequently many of the other wood elements are filled with calcium carbonate[3]. This is found, as a rule, in the heart wood and those tissues of which the cells have a chemical and physical constitution resembling heart wood, such as the pith enclosed by the heart wood and the dead, discolored wood of knots and wounds. This filling is usually so complete that, after such pieces of wood have been burned, solid calcium casts of the cells are found which had contained the carbonate. The process may be explained as follows: whenever opportunity is afforded, the soil water, containing the calcium in the form of bi-carbonate, quickly passes through the wood cells and vessels, and gives off carbon dioxid; it also deposits the calcium, which is no longer soluble, as a precipitate on the inner side of the vessels. In living heart wood which, unlike the growing sapwood, cannot quickly work over the calcium salt, each increase in temperature will cause the giving off of carbon dioxid and induce the precipitation of calcium. In wounds, the carbon dioxid will likewise disappear because of the exposure of the tissue. While the sapwood, which deposits no lime, protects itself from the entrance of air by the formation of tyloses or gum (probably as the result of the entrance of air into vessels previously filled with sap) we find in heart wood a deposition of lime as a means of protection.

In the normal trunk, the formation of heart wood occurs first in the advance stages; after injury, however, it sets in at once and gives rise to the

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[1] Klein, Ludwig, Bemerkenswerte Bäume im Grossherzogtum Baden. Heidelberg 1908. Winter's Universitätsbuchhandlung.

[2] Böhm, Über die Funktion der vegetabilischen Gefässe. Bot. Zeit. 1879, p. 229. The most abundant literature on the formation of Tyloses may be found in Küster, E., Pathologische Pflanzenanatomie, 1903, p. 98.

[3] Molisch, Über die Ablagerung von kohlensaurem Kalk im Stamme dicotyler Holzgewächse. Sitzungsber. d. mathemat.-naturwissenschaftl. Klasse d. k. Akad. d. Wissensch. zu Wien., Vol. LXXXIII, No. 13 (1881).

false heart wood formation[1] which, through the action of fungi and bacteria, can be transformed to heart rot[2].

This attack by micro-organisms has led to the establishment of a number of parasitic diseases, which, however, essentially arise from disturbances in the process of wound healing. As first in importance, we will name

Wound Gum.

Prillieux describes this disease as "*Gommose bacillaire,*" and Viala as "*Roncet.*" The leaves remain green but become irregularly cleft and deformed. In cross section, the wood shows black points and specks which enlarge and loosen its structure. Later the phloem separates from the xylem. On the cut surfaces from which the disease spreads, clefts arise which are infected by saprophytes. Prillieux found that the plant died after three to five years.

The black points in the wood arise from a brown, gummy deposit, which fills the vessels and cells of the wood parenchyma and swarms with bacteria (motile rods). Prillieux found in an infection experiment, made in May in the laboratory, the characteristics of the disease, which bear great resemblance to those of Baccarini's "Malnaro."

Viala and Foëx, as well as Mangin, disagree with Prillieux, in that they hold that the described phenomena of disease can be produced by very different causes and are not absent even in healthy plants.

This difference in opinion was settled by Rathay[3], who proved first of all that gum can occur in perfectly healthy vines. He found gelatinous threads in healthy, one-year-old shoots of *Vitis riparia,* extending from the ducts and composed of gum. The vessels filled with gum ("*gum cells*") may be seen in Fig. 202, *1*. This gave the color reactions of the pentoses. In *Vitis vinifera, V. Labrusca, V. Solonis, V. arizonica,* etc., the reaction is found only in wood two or more years old. If this process occurred in young vines, it could not be observed until July, when the gum is pressed out. In the root, gum formation is less abundant.

As Rathay reports, even in the grapevine, a normal heart wood formation may set in finally in plants twenty years old but takes place irregularly since scattered places of the inner sapwood are involved in the change and produce the brown spots, which Prillieux has described as the symptoms of *Gummose bacillaire.* When such a brown place, extending backward like a

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1 Tuzson, J., Anatomische und mykologische Untersuchungen über die Zersetzung und Konservierung des Rotbuchenholzes. Berlin 1905, cit, Centralbl. für Bakt. 1905, II, Vol. XV, p. 482.

2 Herrmann, Über die Kernbildung bei der Buche. Naturf. Ges. Danzig; cit. Bot. Centralbl. 1905, Vol. XCIX.

3 Rathay, E., Über das Auftreten von Gummi in der Rebe und über die "Gommose bacillaire." Kremla, H., Über Verschiedenheiten im Aschen-Kalk- und Magnesiagehalte von Splint-, Wund- und Wundkernholz der Rebe. Jahresber. d. k. k. önolg. u. pomolog. Lehranstalt in Klosterneuburg. Wien. 1896.

thread in the sapwood (Fig. 202, *3*) is examined, it is found that the broad vessels are filled with a brown gummy mass in which are crystalline precipitates of calcium carbonate (*k*); the contents of the wood parenchyma and medullary ray cells surrounding the vessel are deep brown and the adjoining narrower vessels (*e*) are filled with tyloses. Starch is found only in the sapwood; in the heart wood, instead of the starch, brown grains are found which turn to bluish black with ferric chlorid. Stoppages of the vessels are not found in the sapwood but only in the heart wood. They are caused primarily by tyloses, which occur exclusively in the inner heart wood, while, in the outer heart wood ring, stoppage by gum or calcium predominates. Often whole rows of vessels in summer wood are filled with calcium, usually in the carbonate but at times in the oxalate form (Fig. 202, *4*). The calcium carbonate, deposited in the youngest parts of the heart wood, is dissolved later. In the same way, the great amount of gum in the sapwood disappears with the change to heart wood.

The tissue next to the wound surface in a horizontal wound dies back, more or less. In the living tissue immediately underlying this, the vessels are stopped up by means of gum, farther back by the formation of tyloses. The fact that the vessels have drops and layers of gum only on the parts adjoining the wood parenchyma cells, while the gum is lacking when they adjoin neighboring vessels, proves that it is the wood parenchyma cells which excrete the gum. The changes which characterize the heart wood begin much earlier on wound surfaces than on normal uninjured trunks, extending backward, however, only so far as the wound stimulus was effective. On this account, it is termed "wound heart wood," by some observers "false heart wood" in order to distinguish it from true heart wood. Many bacteria are found near the cut surface but not in the *deeper part of the various centres* of heart wood formation, beginning at the wood surface and extending as light brown tissue stripes through the sapwood. Since the disease agrees in appearance with *Gummose bacillaire,* it is understood to be an immediate result of injury in older parts of the trunk. This wound stimulus may act chiefly on the protoplasm of the wood parenchyma cells surrounding the vessels; it may be continued further because of the continuity of the protoplasm of adjoining cells and may incite the wood parenchyma cells to a premature formation of tyloses. These cells, therefore, grow old and die prematurely. The *normal* secretion of gum, at first very abundant, ceases with the formation of tyloses. The process described is made clearer by an examination of the accompanying figures.

In Fig. 202, *2* (an alcohol preparation from a ten-year branch of *Vitis riparia*), *j* indicates the boundary between two annual rings; *m,m* medullary rays, *g,* gum cells, *g'* vessels with strongly contracted gum contents. At the right (Fig. *1*), are reproduced two gum cells from a one-year-old shoot of *Vitis vinifera* (blue Tollinger); their contracted gum contents are seen in the centre. Only the inner outline of the cell walls is drawn. Fig. *3* is the

Fig. 202. Stoppage of the ducts in a grapevine suffering from wound decay. (After Rathay.)

cross section of a brown wood thread from the sap wood of a very old vine; *j,j,j,j,* the boundaries of the annual rings; *k,* a radial, fibrous crystalline aggregation of calcium carbonate imbedded in the brown gum mass of a broad vessel; the contents of the adjoining wood parenchyma, of the libriform fibres and medullary ray cells are much browned and those lying nearest the vessels *tt,* are filled with tyloses.

Fig. 202, *4,* shows a vessel in cross section, the adjoining wood parenchyma cells from a dead piece of wood lying under the terminal wound of a one-year-old shoot. Besides colorless gum, it contains radially arranged, stem-like aggregations of calcium oxalate. The lower figure is that of a vessel with the surrounding wood parenchyma from the heart wood of a very old grapevine. The vessel is filled with tyloses in which are contained crystalline aggregations of calcium carbonate (after Rathay).

We have cited this case here because, as typical of many other cases, it proves clearly that the gum formation is the result of wound stimulus and at the same time shows how easily diseases may be listed as parasitic, in which is concerned only a subsequent infection by parasites which infest wounds.

This concerns especially herbaceous, fleshy and juicy organs. In this connection, attention should be called to a work by Spieckermann[1], who points out especially the resistance of a cork membrane to bacteria and the necessity of a definite high amount of moisture in the surrounding air as well as the water content of the tissue itself, aside from its specific sensitiveness, in order to make possible bacterial decomposition even on a wound surface.

The Slimy Exudations of Trees.

In connection with the relation of parasitic infection to wound surfaces, already mentioned under "*Gummose bacillaire,*" we will mention here the phenomenon where a usually slimy, or gelatinous, and at time clayey looking exudation is noticeable very frequently in different kinds of trees, and even in summer remains moist and variously colored.

According to our conception of the matter, an excessive bleeding of the trunk is involved here from wounds which cannot heal. Molisch[2] has proved that a local bleeding pressure makes itself felt in every wound which begins to be overgrown. In consequence of the injury, the cambium, as well as the parenchymatous elements of the wood and bark, is incited to increased activity and cell division. With this is connected such an increase of turgor that water is pressed out of the wound often under enormous pressure (at times, 9 atmospheres).

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1 Spieckermann, A., Beitrag zur bakteriellen Wundfäulnis der Kulturflanzen. Landwirtsch. Jahrbücher 1902, p. 155.

2 Molisch, H., Über lokalen Blutungsdruck und seine Ursachen. Bot. Zeit. LX; cit. Just's Jahresber 1902, II, p. 618.

If the analyses of the sap from bleeding grapevines are studied closely[1], it is found that besides small quantities of organic substances, nitrogen, phosphoric acid and calcium are also present, i. e. it may be considered as a nutrient solution very well suited for infection by micro-organisms and for their increase. Ludwig has studied this thoroughly[2]. In a number of publications he describes a *white slimy exudation* in the oak, birch, Saliceae, etc., due to *Leuconostoc Lagerheimii* Ludw. with which are associated various fermenting fungi (*Saccharomyces Ludwigii* Hans, etc.). A *"brown slimy exudation,"* found in apples, birches, poplars, horsechestnuts and other fruit and street trees, showed *Micro-coccus dendroporthos* Ludw., with which is associated *Trula monilioides* Cord. Ludwig found a "red slime" in the late summer on the stumps of old, healthy beeches and observed in it a filament bacterium (Leptothrix?) and *Fusarium moschatum.* He met with the same bacterium in a yellowish white bleeding sap with a gelatinous, granular consistency in lindens and sometimes in birches. He also found toward the middle of April on fresh branch wounds of a hornbeam a milky looking slime which contained *Endomyces vernatis* Ludw. together with alcohol producing yeast. In one of his later works[3] we find mention of mites (Hericia) and eelworms (Rhabditis) as animal companions of such bacteria and fungi. In the Zeitschrift für Pflanzenkrankheiten 1899, p. 13, we find a list of all the infesters of slimy exudations which have been confirmed not only for Germany but also for the tropics. Of course this list will be constantly increased according to whether the micro-organisms, belonging to specific localities, have had opportunity to infect the bleeding wounds of trees.

The organisms here named may be considered to be injurious to trees only in so far as their infection delays or prevents the closing of the wound. Wounds which have been made by frost, lightning, animals, etc., and introduce periodic bleeding, form the primary cause of the slimy exudations. If it is found necessary agriculturally to remove such weakening causes, the only method possible would be to cut out carefully the diseased places and paint the fresh edges of the wound with coal tar.

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[1] Ravizza, F., Über das Thränen der Weinrebe usw. Staz. sperimentali 1888; cit. Biedermann's Centralbl. f. Agrik. 1888, p. 541. According to investigations by Neubauer and v. Canstein (Annalen der Oenologie, Vol. IV, 1874, Part 4, p. 499) the sap of the grapevine (gathered in the dry year 1874) which, in its fresh condition, is as clear as water, and neutral, but easily becomes clouded by bacterial growth and then reacts as an alkali, contained at the time of experiment 2.1204 g. of solid matter per liter, of which 0.7408 g. were mineral elements and 1.3796 g. organic substance. An analysis of the ash gave 10.494 percent. potassium; 1.437 percent. sulfuric acid; 0.188 percent. ferric oxid; 2.822 percent. phosphoric acid; 41.293 percent. calcium; 5.534 percent. magnesia; 34.791 percent. carbon dioxid; 2.857 percent. chlorid; 0.810 percent. silicic acid in the raw ash. Besides these acids, an organic magnesia salt, gum, sugar, and calcium tartarate, inosit, succinic acid, oxalic acid and unknown extractive substances, were found. Rotondi and Ghizzoni (Biedermann's Centralbl. 1879, p. 527) also mention besides starch, sugar which the Neubauer investigations had not found in the fresh sap. Only the volatilized sap which, with the giving off of carbon dioxid and the elimination of calcium phosphate, together with a yellow coloration, had a weakly acid reaction, showed all the sugar reactions.

[2] Ludwig, F., Der Milch- und Rotfluss der Bäume und ihrer Urheber.—Über das Vorkommen des Moschuspilzes im Saftfluss der Bäume; cit. Zeitschr. f. Pflanzenkrankheiten 1892, p. 159, 160.

[3] Ludwig, F., Über die Milben der Baumflüsse und das Vorkommen des Hericia Robini Canestrini in Deutschland. Zeitsch. f. Pflanzenkrankh. 1906, p. 137.

Root Injuries.

Having thoroughly discussed the overgrowth processes of the aërial axis after all kinds of injury, we can quickly summarize the healing of root wounds. They correspond with those of the aërial axis and undergo modifications only inasmuch as the surrounding medium often interferes with the process of overgrowth. For example, if the soil is very moist, the stage of callus formation is prolonged, the transformation of the callus tissue to the firmer overgrowth edge is slower and the possibility of infection by wood destroying fungi greater. These factors, however, become less significant if the root wound surface is exposed to the air. The influence of light, warmth and dryness promotes the closing of the wound and removes any far-reaching influence, from even large wound surfaces, on the condition of health of the whole root. The best proof is found in much frequented forests in the vicinity of large cities where the superficial roots are constantly rubbed bare by pedestrians and, nevertheless, find opportunity to cover the edges of the wound with overgrowth walls. The adjoining figure illustrates such a root so worn that only the first formed annual rings are found to be still intact on the upper side. A cross section shows that no parasitic wound decay has occurred at the wounded place; the wood of the lower side is sound.

Fig. 203. A flat-lying root of the alder barked by the tread of feet.

The wounds produced in transplanting deserve the most consideration. Transplanting is a necessary process, which cannot be omitted in any nursery, for trade requires the delivery to the purchaser of trees which, after transportation to a permanent place, exhibit the greatest possible capacity for vigorous growth and development.

In transplanting older trees with well developed tops and extensive root systems, a cutting off of the larger root-branches cannot be avoided; hence the great danger of attack by parasitic root decay, which gradually advances into the trunk. But even if this danger has been prevented by the painting of the cut places with tar, the transplanting of old trees is always a dangerous operation because the activity of the root system is retarded until new

root fibres may be formed and the top, during this time, must draw water from the reserves stored up in the wood body. Because of the mutual dependence of the subterranean and aërial axes[1] it is necessary to cut back the top of the transplanted tree, corresponding to the change in the root system. The further advanced the foliage of the tree, the more necessary is this pruning. In practice, other means for reducing, as far as possible, the evaporation of the aërial parts are used, such as, for example, the wrapping of the trunk, frequent sprinkling of the top, artificial shade, etc.

Trees are usually sold from nurseries in a leafless condition but even here the quickly developing foliage requires a sufficient supply of water. This can be made possible only by newly formed roots. It is, therefore, of the greatest importance to deliver the trees in such a condition that they will form new roots as quickly and abundantly as possible. This depends upon the method of growing the trees and the way in which the roots have been cut. The older the root is, the scantier the development of new fibrous roots on the cut surface; the larger the cut surface, the more slowly it is overgrown and the greater the danger of root decay. R. Hartig[2] has thoroughly described this for conifers and deciduous trees.

On this account, the first rule is to grow the trees so as to avoid as far as possible wide spreading, large roots, such as trees usually form when developing undisturbed in one place and to produce a root system in the form of a ball of close standing, short but well branched roots. This is done best by repeated cutting of the roots in the first years of growth.

Twisting the long tap root is often recommended instead of cutting it, as this would avoid decay. The widely experienced Göppert[3] holds to this view. As a fact, twisted roots develop lateral roots quickly on their convex side[4]. In the water cultures of fruit trees, which I made in Proskau, some seedlings of the apple, pear, pine, maple, etc., had curved tap roots because they had reached the bottom of the small receptacles and remained there for some time. The root tips of other plants were injured when taken from the sand. The majority of both kinds of seedlings developed lateral roots much sooner than the uninjured experimental plants, set earlier in larger receptacles. This circumstance seems practical, as a confirmation of the view of those who recommend striving for early root branching in transplanting by bending the tap root and not injuring it. We cannot, however, approve of this method; in heavy soils, especially, where we had experimentally planted apple seedlings with cut back tap roots and others with uninjured but spirally twisted ones, the removal from the soil for the second

[1] Kny, L., On correlation in the growth of roots and shoots. (Second paper.) Annals of Botany, Vol. XV, No. 60, Dec., 1901.

[2] Hartig, R., Die Zersetzungserscheinungen des Holzes der Nadelbäume und der Eiche. Berlin 1878.—Lehrbuch d. Pflanzenkrank. 3rd. ed. Berlin 1900. Springer, p. 263.

[3] Göppert, Innere Zustände d. Bäume nach äusseren Verletzungen. Breslau 1873.

[4] Noll, Fr., Über den bestimmenden Einfluss von Wurzelkrümmungen auf Entstehung und Anordnung der Seitenwurzeln. Landwirtsch. Jahrbücher 1900; cit. Zeitschr. f. Pflanzenkrankh. 1902, p. 55.

autumn transplanting was attended with much greater danger for the twisted specimens. To aid in the removal, the plants were pulled slightly and, in doing so, it became evident that the twisted specimens broke very easily at the first bend in the root.

It is, therefore, advisable to cut the seedling tap roots at once at the first transplanting, so that several root branches are formed at the root neck; those near the cut surface develop new lateral axes in the second year.

This makes possible not only an increase of the organs of absorption but also causes the production of a root ball in which the earth is held between the numerous roots.

Prantl[1] first studied thoroughly the anatomical changes which occur when younger roots, especially the germinating ones, are injured. He found in vegetables (peas, horse beans, etc.) that the loss of the tender root tip was completely made good by the development of a new one in which all the tissue systems participated if the injury took place close to the tip of the root. If he cut off the germinating root somewhat further back from the apical cell regeneration took place but all the tissues did not participate in this, only the juvenile vascular strands. The method of cutting, used almost exclusively in general practice, viz: the one injuring the mature tissues, does not bring about a regeneration of the root tip; instead of this, callus formation by the bark body sets in, thereby covering the cut surface.

Němec's[2] work is even more thorough and comprehensive.

In contrast to the assumption that true regenerations, in which the part removed from the individual is directly formed anew in its original shape and with its original physiological peculiarities, rarely occur in the vegetable kingdom, experiments show just the opposite for roots.

It is here only a question of injurying the youngest possible organs. In roots, restitution remains limited really to the zone where the cells on the whole wound surface (possibly with the exception of the epidermis and the outermost bark layers) are still meristematic. As soon as the cells of the outermost bark layers, together with the central rows of the sclerome, approach maturity, the meristematic cell layers alone, adjoining the pericambium, participate in the regeneration. It is found further that the vegetative point of a root, of which the meristematic cells externally appear uniform, still possesses a certain specialization. The cells are not equipotential and can not produce different tissues under arbitrarily changed conditions. Such specific differences are present in the "Statocytes." The mobility of starch grains in these presupposes specific peculiarities of the protoplasm, since in different callus-like hypertrophied cells starch grains are also formed which at times can be still greater than those of the statocytes and yet, under the influence of gravity, cannot be moved easily. The fact that, under the influence of a sufficiently strong centrifugal force, they can move cen-

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1 Prantl, Untersuchungen über die Regeneration des Vegetations-punktes an angiospermen Wurzeln. Würzburg 1873.

2 Němec, B., Studien über die Regeneration. Berlin 1905, Gebr. Bornträger.

trifugally, proves that they are, nevertheless, specifically heavier than the cytoplasm. Therefore, the cytoplasm of the statocytes must have less specific weight and must be very fluid, i. e. it must contain very few elements of considerable consistency. Němec also discovered peculiar cytoplasmic accumulations in the statocytes of the root cap, which certainly represent an especial reaction.

If a young root is cut off above its zone of growth and not within it, no regeneration but substitution takes place, for new lateral roots are produced, of which those nearest the wound surface are caused by their geotropic sensitiveness to grow down more perpendicularly than if they had developed from an uninjured main root. This makes possible the utilization of the soil layers for nutrition, which the perpendicular, downward growing main root would have traversed[1]. A fasciation of the lateral roots takes place at times after injury, or removal of the main root. Lopriore[2] was able to produce this fasciation artifically.

Gnarly Overgrowth Edges.

One universal characteristic in the overgrowth of wounds is that the wood fibres do not always parallel throughout the new structure but are often bent and twisted until at times they are looped. These variations in the course of the fibres form what is termed *"gnarly wood."* The adjoining figure of the overgrowth cap of an oak branch, from which the bark has been removed, gives the best insight into this. The oak furnishes especially good examples of a complete closing of large wound surfaces by overgrowth and the luxuriance of the uniting wound edge not infrequently brings about the condition where, for example, in sawed off, larger branches, the newly formed tissue does not have a flat surface but one more or less strongly convex, becoming hemispherical to spherical in form. In such overgrowth caps small centres are often found, the so-called gnarl eyes (Fig. 203, *a*), around which variously twisted wood fibres (*p*) are deposited. By the term "gnarl eyes," however, actual buds are not understood but rather depressed tissue centres, around which are deposited the wood fibres in the form of a bowl and later serpentinely twisted; in this way representing the *"curly grain"* in wood. While a spear-like, woody excrescence appears where actual eyes are produced, in gnarl eyes a deep depression is found formed of parenchymatous tissue, often increased by the rounding up and separation of the cells. Wood is deposited around this depression, normally composed of wood cells, medullary ray cells and vessels. The abnormality lies only in the bowl-like arrangement, recalling the gnarl tuber, and the frequent occurrence of medullary ray structures greatly broadened and resembling medullary spots, which at times can develop into secondary centres.

[1] Bruck, W. F., Untersuchungen über den Einfluss von Aussenbedingungen auf die Orientierung von Seitenwurzeln. Zeitsch. f. allgem. Physiologie Vol., III, 1904, Part 4.

[2] Lopriore, G., I caratteri anatomici delle radici nastriformi. Roma 1902. Note sulla biologia dei processi di rigenerazione delle cormofite, etc. Atti Acad. Gioenia, Catania 1906, Vol. XXI.

We consider the curly or gnarly wood only as an extreme case of perfectly normal processes, in the variation of the wood fibres when obstacles occur which prevent their longitudinal arrangement in the part of the plant. Such obstacles can differ greatly. Each normal branch insertion becomes the cause of a change in the course of the wood fibres surrounding it. The new formation of wood bodies within the bark, described under bark tubers, represents a further cause. Finally, however, we find the most varied phenomena of arrestment in the formation of an annual ring, produced by differences in tension in the growing axis. Such differences in tension are constantly present and are often strengthened by external influences. Frost action, for example, which causes the formation of parenchyma bands, is

Fig. 204. Gnarlly wood structure of the overgrowth cap of the stump of an oak branch.

of especial significance. Another external cause is the contact of one branch with another. Besides mechanical pressure, conditions of light are also of influence; they cause variations in the nutrition of the different sides of the cambial ring. Internal processes of growth, as, for example, the rapid outpushing of a suddenly broadened medullary ray, are also of importance. These can distend the bark into knobs, causing a repression in the growth of the adjoining wood layers and the like. All such disturbances must change the pressure conditions which the bark girdle in its entirety exercises on the cambium and will, therefore, influence the development of the wood formed from it. We find in the spiral twisting of the wood body in every trunk, how greatly the course of the fibres is influenced by the

pressure conditions, even in the normal trunk. Our experiments in binding a wire ring around a growing axis prove how much the wood fibres can be forced from a longitudinal into an approximately horizontal position by pressure.

It is, therefore, the different pressure constantly endured and exercised by the bark girdle, which conditions the development and course of the wood fibres. Therefore, to explain gnarly wound wood, it is necessary to assume a theory of the polarity of the cells and the displacement of like poles as represented by Voechting and Mäule[1].

Bark Tubers.

In concluding the chapter on the processes of wound healing, we have still to consider the production of spherical woody swellings, or tuberous outgrowths of the bark of trees and (more rarely) herbaceous plants. These structures are generally called "wood tubers" or "gnarl tubers." Their structure and production differ, thus necessitating a subdivision into separate groups. Their character as correlative hyperplasias is their common quality. They are to be considered as the counteraction of the organism to previous phenomena of arrestment. The arrestment can consist in the cessation of the development of a bud or, independent of any bud, can be produced by the death of scattered tissue groups in the bark. The dying of different cell groups in the bark body of the woody axes occurs extensively. Frost and heat, local increase in pressure and the like, can cause the death of cell groups without any injury to the whole organism, which responds, not infrequently, by an increased new formation near the centre of arrestment. The dead tissue groups are sometimes only encysted by cork layers, sometimes also accompanied by cell layers, increasing for some time, or permanently, according to the time and kind of disturbance and the amount of the nutritive supply in the surrounding tissue. The cell layers either produce only parenchymatous protuberances or cause the formation of new wood bodies, spherical in arrangement, with gnarled fibres. The latter process can increase to the production of independent tuberous wood bodies within the bark.

I have made no personal study of the first group of bark tubers, the production of which is traced back to bud primordia retarded in development, and in consequence will quote the descriptions of earlier authors. Trècul[2] should be named first among these. He describes in detail some cases of tuber formation (in the oak and hornbeam) and comes to the conclusion that the tubers always owe their production to a bud which originally is directly connected vascularly with the wood body of the branch or trunk. Such a bud may lie dormant a number of years without projecting more

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1 Mäule, C., Der Faserverlauf im Wundholz. Bibliotheca botanica Part 33. Erwin Naegele. Stuttgart 1896.

2 Trécul, Mémoire sur le developement des loupes et des broussins, envisagés au point de vue de l'accroissement en diamètre des arbres dicotyledonés. Annales des scienc. nat. 3 serie. Botanique t. XX, 1853, p. 65.

than 2 mm. (at least in the hornbeam) above the surface of the bark. After a few years of such lethargy, the fibro-vascular body can renew its activity and develop into a spherical, oval or even ellipical wood tuber.

The death of dormant buds occurs of itself after a considerable number of years, if not hastened by external circumstances, since the connection is broken between the part of the bud lying in the bark and that in the wood body by the interposition of the wood mantle of the branch which bears the bud. The outer part of the bud, covered with scales and lying on top of the bark, remains in place for some time; it dries up very slowly and finally is thrown off.

This bud, originally attached to the wood body, can also be loosened by the splitting off of its fibro-vascular bundle from the wood of the trunk. As a rule, the portions of the bud which project above the bark surface die, while its fibro-vascular body, thus isolated in the bark continues to form new wood layers and its own bark without the aid of foliage; it must, therefore, draw its plastic material from the surrounding green bark of the trunk. This growth may continue for years; the outer side of the wood tubers may die from the destruction of external agents and, nevertheless, the tubers can continue to form new wood on the inner side. In the red beech, as in the hornbeam, these tubers are produced from adventitious buds.

Th. Hartig[1] describes the production of tubers in the red beech from preventitious buds. The weak basal buds in the red beech die after possibly twenty years inasmuch as the bud stem, lying in the bark, is separated from the part of the bud in the wood by the interposition of a completely uniform, connected wood layer of the branch bearing the bud. The part of the preventitious bud lying in the bark, however, can remain alive for some time and leading, as it were, a parasitic life, grow by continued, concentric wood formation, into those wood tubers which, as large as peas or hazelnuts, project above the bark and are peculiar to the luxuriantly growing beech trunk in middle age.

Dutrochet[2], whose personal view is related to the then prevailing bud root theory, describes the tuberous outgrowths as bud embryos (mérithalles). Unlike the normal buds of the axis, these are not inserted on top of and between each other but remain without any connection with the other bud embryos and their vascular strands and, therefore, do not form a part of the axial cylinder. So long as such an embryo, the primordium of an adventitious bud, remains isolated in the other tissues, it develops no leaf and no bud but retains its spherical form and grows by constantly developing new wood layers, covered with their own bark. If this isolated wood body, the primordium of an adventitious bud, finally comes in contact with the axial body, its own bark disappears because of the pressure and the wood

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1 Hartig, Th., Vollständige Naturgeschichte der forstlichen Kulturpflanzen Deutschlands, p. 176. Berlin 1852.

2 Observations sur la forme primitive des embryons gemmaires des arbres dicotyledonés, 1837. (Nouv. Mém. du Mus. d'Hist. nat. IV).

knot forms a real bud, which develops leaves. It now represents a gnarl tuber (loupe); the coalescence of several such tubers forms a wen (broussin).

This theory differs from those developed earlier, inasmuch as in it the bud is considered the final product of the tuber formation, while in the others it is held to be the initial one. Lindley[1], who describes the tubers mentioned by Dutrochet in the beech, cedar and poplar and who found in one poplar[2] that branches could develop from them, considers them to be produced from adventitious buds and cites a further case in old olive trees, mentioned by Manetti. He says that the tubers (gnaurs) in these trees were cut out, together with a part of the bark, and planted and that these tubers, which Manetti called Uovoli, gave young plants. Treviranus, to whom Morren sent some cedar tubers, confirms in general the structure of the tubers described by Dutrochet. He places in the same category the phenomena of the isolated vascular bundles (leaf trace strands) in climbing Sapindaceae, *Calycanthus floridus* and *C. praecox*, some Bignoniaceae, etc.

Schacht[3] explains the tubers in the bark of poplars, lindens, beeches, etc., as dwarfed branches which have grown in circumference but not in length. While Hartig points to the first beginnings of the tubers in dormant buds, Ratzeburg[4] lays stress upon the bark as the productive centre of the same beech tubers and says explicitly that they do not extend to the wood body. Similarly Rossmässler[5] declares that the tubers of the mountain ash (*Sorbus aucuparia*), which he investigated, lie only in the bark and have no connection with the wood body; Kotschy[6], on the other hand, describes bark tubers 10 to 15 cm. large on the old trunks of the Lebanon cedar, as gnarly, woody excrescences, firmly fixed in the bark, which are connected with the mother trunk by a few vascular bundles. Masters[7] also suspects that some of the tubers (*gnaurs* or *burrs*) in the elm, etc., as also in many apple varieties, are only aggregations of adventitious buds.

A work by Krick[8] reconciles the apparently contradictory theories. He has determined that the bark tubers (Sphaeroplasts) of the red beech develop in connection with preventitious buds, either separating from the wood axis of the trunk, or developing independently in the bark. In the latter case the tubers have a woody, cork, or phloem core but never real pith.

The latter kind of tuber formation which takes place in the bark parenchyma, outside of the primary group of phloem fibres, carries us over to the second group of bark tubers in which certainly no bud primordia participate.

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1 Lindley, Theory of Horticulture 198. Translated by Treviranus 1850, p. 87.
2 Loc. cit., p. 224.
3 Schacht, Der Baum, 1853, p. 134.
4 Ratzeburg, Die Standortsgewächse und Unkräuter Deutschlands und der Schweiz. Berlin 1859, p. 243, Note 1.
5 Rossmässler, Versuch einer anatomischen Charakteristik des Holzkörpers der deutschen Waldbäume. Tharandt. Jahrb. 1847, Vol. IV, p. 208.
6 Kotschy, Reise in den cilicischen Taurus. Gotha 1858, p. 267.
7 Masters, Vegetable Teratology 1869, p. 247.
8 Krick, Fr., Über die Rindenknollen der Rotbuche. Bibliotheca botanica 1891, Part 25; cit. Bot. Zeit. 1892, p. 401.

In this we have to mention first Gernet's[1] investigations of tuber formation in *Sorbus aucuparia.* He found the dead tubers so loosely attached to the bark that they could easily be lifted out with the finger nail while the living ones were apparently firmly fixed in the sapwood. Nevertheless, they proved to be "completely separated from it and appeared as bodies possibly belonging in some way to the phloem because the very reddish color of their smooth under end corresponds to that of the phloem." Most tubers, when cut through, show several centres about which complete wood layers have developed in 13 to 15 annual layers, provided with vessels and medullary rays and agreeing in their cell structure with the wood of the trunk. The course of the wood layers was gnarly. The annual rings were almost always broader in the under half of the tubers toward the trunk than in the upper one, projecting from the trunk. It was not possible to prove any connection with a bud. Even when a tuber lay near a wen, no connection could be found with any of the many bud cones of the wen.

Unfortunately, Gernet had no opportunity to study the initial stages of tuber development; the youngest stages in his material were tubercles 0.5 mm. in size, still completely enclosed in the bark, without having caused any external protuberance. They lay outside the phloem fibre and were spherical or ellipsoid and showed several centres about which the wood body had already been deposited. This consisted of parenchymatously formed cells in which a differentiation of medullary ray cells became recognizable in longitudinal sections. The first indications of vessels may be considered to be represented by a few cells with large lumina but still lying above each other with almost horizontal, unbroken walls and containing less starch, or none at all. The farther all these cells lay from the centre, the more clearly noticeable became the lessening of their radii and the lengthening of their tangential axes; their cross section approximated that of summer wood. In older tubercles are found at first sharply differentiated a few pitted vessels and a clearly recognizable central parenchymatous centre, rich in starch. The wood body was surrounded by a cambial zone and its own bark. In the upper half of the tubers, cork formation took place at times in the inner bark. The outer side of this newly produced cork zone was united, not infrequently, with the cork zone of the trunk. The part of the bark isolated by such a cork zone (Gernet's "cork dam") loses its starch grains, becomes filled with air and dies gradually so that the outer side of the tuber body contains dead tissue. As a rule, the appearance of these cork layers also introduces the death of the tuber, which occurs within the next few years. The under half of such diseased tubers, as well as that of perfectly healthy ones, retains its living bark tissue and the formation of the bark body progresses with that of the wood body. From this we may conclude that the tuber grows downward and thus its upper part gradually projects above the surface of the bark of the trunk by rupturing it.

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1 Gernet, C. v., Über die Rindenknollen von **Sorbus aucuparia.** Moskau 1860.

Judging by this, Gernet arrives at the conclusion that, even if he did not know the initial stages of the tubers, he must still deny any connection between them and the wood body of the trunk and can consider the tubers to be produced neither from preventitious nor adventitious buds.

Having investigated the tubers of apple trees, I can confirm absolutely this point of view. For my investigation I had at my disposal tubers varying in size from a millet grain to a pea; they came from the base of the trunk of a young apple tree, possibly eight years old. The tubers lay in the outer bark, from which they could be easily separated. The under side was either completely covered with a smooth bark (Fig. 205, *1 a*) or showed a brownish, dry point, without any bark and somewhat depressed (*1-k*) which was surrounded by a green circular bark wall.

Fig. 205, *2* gives the median cross section of the latter kind of tuber.

In this we see a median core (*2,b*) consisting of two phloem fibre groups separated by a little parenchyma; other tubers have only one phloem strand in the core, or two or three isolated cores. Around the bundle are deposited cells, parenchymatous in form, with slightly lignified walls and arranged radially. It is evident that they are formed after the manner of cork cells. At times only a group of thick-walled, brown parenchyma cells, with or without starch or phloem fibres, is found in the centre of the tuber; yet this is a more rare case. Finally, tubers are formed now and then with a small central cavity, filled with the brown remains of cells.

The radially arranged, circular zone of lignified, parenchymatous cells passes over gradually into narrow, thick-walled, somewhat elongated wood parenchyma cells, horizontal or diagonal in course, between which lie scattered, short, broad vessels with simple pits (Fig. 205, *2,g'*). These groups are already divided into numerous circles of vascular bundles by approximately cubical medullary rays deposited in one to three rows. The phenomenon begins here which continues in alternative zones out to the periphery of the wood body, viz: that the elements of the one part of the bundle, which lies between two medullary rays, show a course differing from that in the adjacent bundle. While the cells and vessels of the one part seem cut crosswise (*2 h"*), the fibres of the adjacent part are cut longitudinally. This is found in trunks which have overgrown some constriction and may be explained only by the theory that the different parts of the cambium of the wood body, which curves about the core like a shell, are exposed *simultaneously to different* pressure and strain. Since the young tuber body has no exact spherical form but is only approximately round, the parts which are to overgrow the corners already formed elongate more in the same length of time.

The elements become narrowed, longer and thicker-walled toward the outside of the tuber until they have nearly the length, form and, in places, arrangement of the normal wood body.

Inside the tuber, as in the wood, a differentiation of the annual rings into spring and summer wood is found, so that it is evident that the tuber

is a wood body, provided with the peculiarities of the species and isolated in the bark; its elements grow in all directions around one or more elongated or short cores.

Fig. 205. Bark tubers from an apple trunk.

The cambial zone (*2 c*), surrounding the wood, annually produces a new bark (*2 rs*) and, in injuries, heals the wounds just as in a normal trunk. Such an injury has taken place in Fig. 204,*2* since the bark and sapwood have been removed from the tip of the tuber by some external influence. In

consequence of this a normal overgrowth edge (*2 u*) completely covered with bark is produced which forms the outwardly noticeable circular wall about the tip of the tuber (Fig. 204, *1k*).

The fact, noticeable at first, that phloem fibres are found in the centre of a wood body, leads to the conclusion that the tissue surrounding the phloem fibre groups is the place where the formation of the wood begins. This conclusion is still more strengthened by the structures near the tubers. Frequently younger phloem bundles are found here, even at times the very youngest ones just appearing from the cambial zone, which are surrounded by peculiar, radially arranged cells (Fig. 204,*5*). In some cases these plate-like cells of the *"phloem circumvallation"* turn blue with iodine and sulfuric acid; in most cases, however, they turn yellow. This shows that, as a fact, the tissue surrounding the phloem group tends easily to cell increase.

The overgrowth of the phloem by cork tissue is in no way restricted to the tissues surrounding the gnarl tuber. In the trees I have investigated it was found in different places after many an injury. In this, however, the cells *always* have the character of cork cells and serve excellently to cut off a diseased phloem bundle from the healthy wood. Any one who has worked much with diseased trees knows how sensitive the bark cells are which have apparently so resistant a structure. Their brown color and the more distinct appearance of their layers make it possible to trace the disease deeper into the healthy tissue than can be done in the surrounding bark parenchyma.

The overgrowth of the phloem begins, as a rule, in the cells of the phloem sheath and remains limited at times to one side, or at least develops more vigorously on the outerside. Similar phenomena, like the overgrowth of the phloem bundles, are found also in some parts of the parenchyma. Without any reason, known as yet, the parenchyma here substitutes for the core a meristem zone in the bark which increases by growing around the centre of fibres, thus beginning the formation of bark tubers. Such tubers have usually a somewhat regular structure since the course of the tissue elements in several annual rings keeps to the same direction. In a median longitudinal section which may be recognized by the fact that the medullary rays lie in approximately the same plane, the bent vessels are cut through their whole length so that they interrupt the dark, parallel wood cell zones as clear, concentric rings.

The drawings (Fig. 206) made from the bark of a healthy one-year-old pear twig give an interesting contribution to the explanation of tuber formation. We see in Fig. 206, *1*, the basal part of a very strong one-year-old pear shoot of which the buds (*a*) are set in the normal two-fifths position; *b* is the one-sided swelling in the centre of the internode, reproduced again in cross section in Fig. 206, *5*, cut through in the deepest part, which is turned toward the base of the twig, in Fig. 206, *3* in the median region, and in Fig. 206, *4* in the highest zone. In Fig. 206, *3*, *4*, *5*, the same letters indicate the same parts; *r*, the bark, g' and g^2, etc., the bark vascular bundles in various

stages of development. It is evident that those first formed also become smaller at first after entering the axis. *m* is the pith; *m b*, the pith bridge of a central leaf trace, of which the secondary bundles are unequally developed; *m st*, medullary rays; *hb* phloem fibre groups, which compose the central core of the wood cord formed in the bark. In Fig. 206, *4 rt* is the bark killed by pressure and pressed into the trunk by the xylem strand formed in the axis of the branch. Fig. 206, *5* g^3 indicates a xylem strand with the beginnings of overgrowth; this is seen to be more strongly developed on the outer side. Fig. 206, *3 g'* is a xylem strand which has not closed completely into a wood cylinder. Its formation took place as follows: cell increase began on the outer side of the phloem fibre group in the phloem sheath and led to the formation of vascular elements and wood cells. The one-sided wood body thus produced is closed by the gradual union of the two edges, turned to the centre and growing toward each other. Fig. 206, *5 c'* is the cambial zone of a xylem strand already closed internally but still pressed into a kidney shape at the place of union. Fig. 206,*2* gives a part of Fig. 206,*3 g'* somewhat magnified.

In Fig. 206,*2* is seen the complete correspondence with the centre of the gnarled tuber in the apple. *hb* is the phloem fibre group; *p*, the wood parenchyma; *g*, the vessels; *x*, short, cross-cut wood cells; *x'*, wood cells, extending horizontally from the inner convexity of the wood cord at the place where the two edges have united; *m* represents the rows of medullary rays spread out like grasping arms; *c*, the cambial zone surrounding the strand; *r*, the youngest bark parenchyma of the specialized zone of bark.

The xylem strands (Fig. 206,*5*) are, therefore, produced at the base of the swelling by an unusually abundant nutrition of the phloem sheath; their primordia lie at unequal heights. When enlarging, they compress at first the bark tissue (Fig. 206,*3*) which separates them from each other and finally also the tissue lying above them, which separates them from the axial cylinder and is found later as a brown mass in the centre of the wood body (Fig. 206,*4 rt*). With their entrance into the axial cylinder, the form of the xylem strands in the bark is changed; the core becomes eccentric and finally pressed back to the tip of the wedge-shaped strand as shown in Fig. 206,*4* g', g^2, g^3. The change of form is, therefore, exactly the reverse of that undergone by the normal vascular bundle which enters the bark from the axial cylinder.

Farther out the branch becomes normal[1].

The occurrence of bark-produced wood strands, therefore, explains as follows the production of the gnarl tuber. The mature tuber is a wood sphere *isolated* in the bark, of which the upper surface is composed of a cambial and bark mantle, receiving its nourishment from the surrounding bark tissue. According to the investigations of the above-named scientists,

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[1] On the similarity of this formation of the secondary wood with that in the Sapindaceae compare Sorauer, Die Knollenmaser der Kernobstbäume. Landwirtsch. Versuchsstationen 1878.

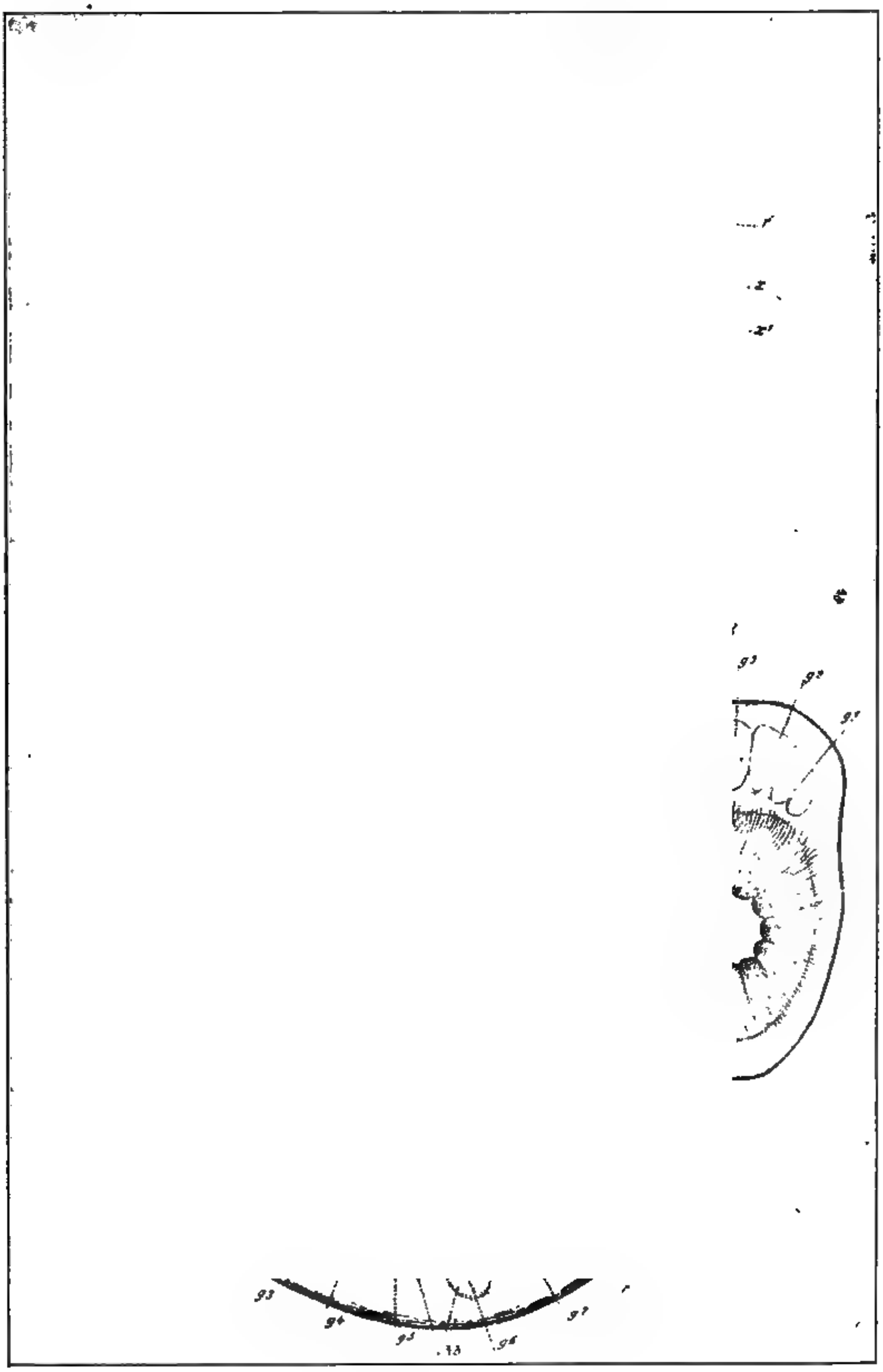

Fig. 206. Production of isolated wood centres in the bark of a one year old pear branch.

which need repeating, the gnarl tubers, or tuber gnarls, can develop from a dormant bud and are, therefore, originally connected with the wood body of the branch. In many cases, however, they are produced as bowl-like wood deposits around a group of phloem, fibres, or some other bark tissue group without any connection with the wood cylinder or a bud primordium. The tuber is gradually pushed out into the outermost regions of the bark, which is beginning to form the cortex; the longitudinally elongated xylem strands of the bark, related to the tuber formation, can press back into the axial body and become elements of the normal wood cylinder of a branch. External wounds in the tuber body are healed by overgrowth, just as in the normal branch and there is no reason to doubt that adventitious buds can develop from the overgrowth edges as well as from the normal bark of the tuber, as has been stated for the olive.

Mention should be made of the fact that the large spherical swellings, produced on oak branches by the overgrowth of places where *Loranthus europaeus* had grown, have also been termed gnarl tubers or heads. According to our division of the subject, these are not actual "gnarls" but gnarly overgrowth edges.

Tine Tammes[1] describes as abnormal overgrowths the peculiar cone-like processes on *Fagus silvatica* which usually grow broader on one side and overlap. Investigation shows that the stump of a branch is involved here, which has been closed by gnarly, hypertrophied wound edges. The hypertrophy has been caused by the severe pruning of the trees on account of which a superabundance of plastic material is deposited at the remaining centres of growth.

Peters, in his observations on *Helianthus annuus* and *Polygonum cuspidatum*[2] gives an example of bark tubers in herbaceous plants. The tubers produced in the middle bark should be considered as the reaction of the plant to wound stimulus. A few cell groups in the bark die and dry up; the cavity thus produced becomes surrounded by a cambial zone which forms wood on the inner side and bark tissue on the outer.

Th. Hartig[3] mentions examples of tuber formation in roots when describing the fact that young aspens occur in great numbers on cleared tracts where no seed bearing trees had stood for some time. As Th. Hartig explains, the little plants owe their existence to the continued growth of roots left from long dead and outwardly vanished trees.

The basis of *root growth* in these cases is always a tuber-like woody thickening of a weak root strand. The tubers themselves are somewhat like those at the gnarly base of old oaks or lindens and those in the bark of the red beech; they are the woody trunk of a dormant eye which, completely individualized, lives a parasitic life on the root of the parent plant "like the dormant eyes of the American species of pine." The aspen roots are kept

[1] Tine Tammes, Über eigentumlich gebildete Maserbildungen an Zweigen von **Fagus silvatica** L. Recueil des travaux bot. Neerl. No. 1. Groningen 1904.
[2] Cit. Zeitschr. f. Pflanzenkrankh. 1905, p. ?6.
[3] Loc. cit., p. 429.

alive by these tubers without any growth of the feeding root. As a rule, the piece of root, bearing the tuber, is found to be dead and decaying a few centimeters from the tuber. Andreae[1] describes gnarled tubers on the roots of *Ailanthus glandulosa;* they are produced from roots and from *branch* primordia.

In connection with this, a structure may be mentioned here which is often described as the *Club root of beets*[2] but has not yet been sufficiently explained. Usually in dry soil there appears near the crown, or a little farther down, a spherical swelling covered with cork, resembling the root body in structure but differing from it in composition because of a greater water, ash and protein content. The vascular body shows that the swelling should be considered as the enlargement of a vascular ring of the parent root and may, therefore, be considered an offshoot of it probably caused by an excess of nitrogen after some injury[3]. The swelling is not parasitic but, because of its porous bark structure and its inert sugar content, is easily infested by animal and vegetable enemies.

LEAF INJURIES.

In consideration of the fact that the results of injuries appear more clearly in leaves and other fleshy parts of plants, we will call attention to the conditions which we call *wound stimulus.* The first effect of the stimulus, which is exercised on the organ by every injury, may well consist in a traumatropic deposition of protoplasm in the tissue immediately adjacent to the wound surface. According to Nestler's[4] investigations, the protoplasm in the uninjured cells collects on the side toward the wound and somewhat later the nucleus moves toward that side. This action of the stimulus extends a few cell rows into the healthy tissue and after about 48 hours reaches its maximum. After this, a more or less complete return to the normal condition sets in. This change in position seems to take place more quickly in the light than in the dark.

In the same way, the chlorophyll apparatus often undergoes a considerable change of position[5]. In many cases an increase of respiration may be noticed at the same time; in the fleshy parts of plants, especially, a rise in temperature could be proved which has been called fever reaction[6]. The production of carbon dioxid in wounded leaves is said to be especially increased if they are poor in carbon-hydrates[7]. The reactions set in earlier

[1] Andreae, Über abnorme Wurzelanschwellungen bei **Ailanthus glandulosa.** Inaugural dissertation. Erlangen 1894.

[2] Briem, H., Strohmer und Stift, Die Wurzelkropfbildung bei der Zuckerrübe. Österr. Ungar. Z. f. Zuckerindustrie 1892, Part 2.

[3] Geschwin, Le goitre de la betterave. La sucrerie indigène. Cit. Bot. Centralbl. f. Bakt. II, 1905, p. 486.

[4] Nestler, A., Über die durch Wundreiz bewirkten Bewegungserscheinungen des Zellkerns und des Protoplasmas. S. Akad. Wien CVII, I, 1898.

[5] Pfeffer, W., Pflanzenphysiologie. 2nd Ed. 1904, Vol. II, p. 819. Here also literature on the action of Wound Stimulus.

[6] Richards, Herbert Maule, The evolution of heat by wounded plants. Annals of Bot. XI; cit. Bot. Jahresber. 1897, p. 99.

[7] Doroféjew, N., Zur Kenntnis der Atmung verletzter Blätter. Ber. d. Deutsch. Bot. Ges. XX, 1902, p. 396.

or later according to the degree of injury. According to Townsend[1] the hastening of growth becomes evident in 6 to 24 hours after slight injuries, while severe injuries at first cause an arrestment before the increase in rate begins, which, according to the plant, reaches its maximum in 12 to 96 hours and then gradually returns to the normal condition. Krassnosselsky[2] traces the increase of respiration to an increase of the respiratory enzyme. He carries out further Kovchoff's experiments which show that an increase in the whole amount of protein and especially of the nucleo-proteids takes place after an injury and then proves (in injured bulbs) that the sap contains more oxydases than does that from uninjured specimens. The same is true of potatoes.

The subsequent reactions of leaves after injury vary greatly according to the species of the plant, the age of the leaf and the time of injury. We

Fig. 207. Injury to a leaf of Leucojum vernum, which is being closed by callus formation. (After Frank.)

will content ourselves with discussing the two extremes, viz: the reaction of a tough leathery leaf and that of a fleshy one. In the former, *Prunus Laurocerasus* represents a case in which a sloughing process of the injured cell group is connected with the injury as has already been mentioned under the results of spraying with copper. According to Blackman[3] and Matthaei[4] either the injured cells alone die, or those immediately adjoining them, according to the part of the leaf injured. A brown zone with a lighter colored centre is produced around the wound. The epidermis splits in this hyaline region and colorless, very thin-walled, cells grow out of the adjoin-

[1] Townsend, C. D., The correlation of growth under the influence of injuries; cit. Bot. Jahresber. 1897, I, p. 98.
[2] Krassnosselsky, Bildung der Atmungsenzyme in verletzten Pflanzen. Ber. d. Deutsch. Bot. Ges. 1905, Vol. XXIII, p. 143.
[3] Ber. d. Deutsch. Bot. Ges. 1903, p. 165.
[4] Blackman, F. F., and Matthaei, G. L., On the reaction of leaves to traumatic stimulation. Ann. Bot. XV; cit. Zeitschr. f. Pflanzenkrankh. 1902, p. 61.

ing mesophyll. These form a cuticle and thus represent a complete covering of the wounded leaf surface. When this covering is complete, the dead tissue is thrown off. In this the pressure of moist air is taken for granted. In other cases a normal periderm is formed from several cell layers which suffices as a protection for the healthy leaf tissue.

The second case of the healing of leaf injuries, viz: by callus formation, is explained by the accompanying figure. It is the cut wound from a cut on *Leucojum vernum.* The wound lay in the open space between the two tissues of lamellae *f* and *f'*; *v v v v'* are the edges of the wound with the dead pieces of tissue. The wound cavity is now filled by the callus cells developing by elongation from the fresh tissue, which lack chlorophyll and have suberized walls. The normal condition of the leaf is represented at the left side of the figure where *i i* indicates a large air chamber; the tissue surrounding it has not been changed by wound stimulus. *o* is the upper and *u* the under side of the leaf. Many fleshy leaves react according to this scheme, but their processes of healing vary greatly, depending on the subsequent participation of the process of cork formation. Complete union of the edges of the wound can also take place, as may be observed, for example, in the cut surfaces of fleshy roots and tubers[1]. The union is sometimes the result of organic coalescence, sometimes only a cementing of the surfaces since the cut cells are changed into a gum-like mass by the swelling and disintegration of their walls.

The leaf can under certain circumstances reproduce the part artificially removed (regeneration, according to Küster) or form a compensating organ (restitution[2]) according to the specific character of the leaf, its youth and its distance from the reserve-substance containers.

Frequently whole leaves, or pieces of leaves, removed from the plant, can form new roots and aërial axes. This capacity is utilized for

Leaf Cuttings.

The best known and most frequent use of leaf propagation is found in begonia culture. According to Hansen[3], in the various varieties of *Begonia Rex* wounds produced by slashing the nerves of the leaf lying flat on the soil are closed at once by callus. In this way a tuberous tissue is formed on the mother leaf from which tissue, or that immediately surrounding it, roots develop; later, sprouts are formed from the same tissue, which, however, do not develop their own roots but are nourished by the above-mentioned roots of the callus. Sprouts develop there from one or a few cells of the epidermis near the cut rib, sometimes nearer, sometimes farther from the wound. In such cells, a horizontal partition wall is pro-

1 Figdor, Wilhelm, Studien über die Erscheinung der Verwachsung im Planzenreiche. Sitzungsber. d. Akad. d. Wissensch. Wien; cit. Bot. Zeit. 1891, No. 23.

2 Figdor, Wilhelm, Über Regeneration der Blattspreite von Scolopendrium. Bericht d. Deutsch. Bot. Ges. 1906, Vol. XXIV, Part 1.—Figdor, Wilhelm, Über Restitutionserscheinungen an Blättern von Gesneriaceen. Jahrb. f. wiss. Bot. 1907, Vol. XLIV, Part 1.

3 Hansen, Ad., Vorläufige Mitteilung. Flora 1879, p. 254.

duced at first and gradually by further division the meristem of the young sprout from which a roll differentiates as the first leaf.

The roots are formed laterally from a few cells lying near the cambial zone of the vascular bundle. These, therefore, "endogenously" formed roots soon rupture the overlying tissue. As Fr. Regel[1] states, the roots of begonia branch cuttings can also arise from the inter-fascicular cambium. This author, who has investigated several other begonias beside *Begonia Rex* with rhizome-like, recumbent petioles, as, for example, *Begonia imperialis* and *B. xanthina,* mentions that the formation of buds also takes place on the leaf blade near the incisions. After the epidermal cells have divided, the underlying collenchyma and the ground tissue are also drawn into the new formation and help in producing the mound of cicatrization tissue at the place cut. This tissue differs from that of branch cuttings only in the fact that here the epidermis participates in the cell increase.

This activity of the epidermis can become of very especial physiological importance immediately after the cut is made since a few of the upper epidermal cells near the wound elongate like hairs (pseudo-root hairs) and, without doubt, develop a root-like activity until the true roots are formed.

In the adjoining Fig. 208 are shown the new structures on the cut surface of a larger leaf rib in a hybrid Rex begonia. *A* indicates the old part of the leaf, *B* the new structures. At first an abundant callus tissue (*c*) develops from the cut and soon shows an apical growth of its cell rows but indicates by the parallel edges of the cork cells that it is in the process of transition to overgrowth edges. The endogenously formed new root (*w*) breaks out on the under side of the boundary between the callus and the old leaf tissue, while on the upper side, two new bud primordia have already been formed. The younger one of these shows at *d* the meristematic tissue of the young bud with the epidermis (*e*). This meristematic tissue is produced by the division of the original epidermal cells and the sub-epidermal tissue. The second bud has been formed earlier at a point lying farther away from the cut and already is further developed. The real bud cone (*d*) is already overgrown by a more convex leaf primordium (*bl*) into which extend young spiral vessels (*f*). The vascular bundle ring of the older part of the leaf is indicated at *g,* while *t* indicates the vascular bundles extending into the new root.

Kny[2] noted that the vascular bundles had become larger on the petioles of *Begonia Rex,* on which adventitious sprouts had been produced. The cambium, like the adjacent ground tissue, had continued its cell division, whereby the new walls between the adjacent bundles were predominantly parallel to the outer surface of the petioles. Kny regarded this as the

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1 Regel, Fr., Die Vermehrung der Begoniaceen aus ihren Blättern usw. Jena'ische Zeitschr. f. Naturwiss. 1876, p. 477; cit. Bot. Jahresber. 1876, p. 423, 439, 452, etc.

2 Kny, L., Über die Einschaltung des Blattes in das Verzweigungssystem der Pflanze. From "Naturw. Wochenschrift" 1904; cit. in Bot. Centralbl. (Lotsy) 1904, No. 50, p. 612.

beginning of an inter-fascicular cambium which, developing further, would have closed the peripheral bundles into a circle.

From the many observations already made on leaf cuttings, the assumption is justifiable that the processes described above for begonia may occur also in many other leaf cuttings. The foliage shoots develop from more or less superficial cells; the root primordia are produced from the cells bordering the cambial zone and either break through the old tissue of the cuttings or arise from the cicatrization tissue of the wound. Variations in the different genera are usually unimportant and differences of opinion among

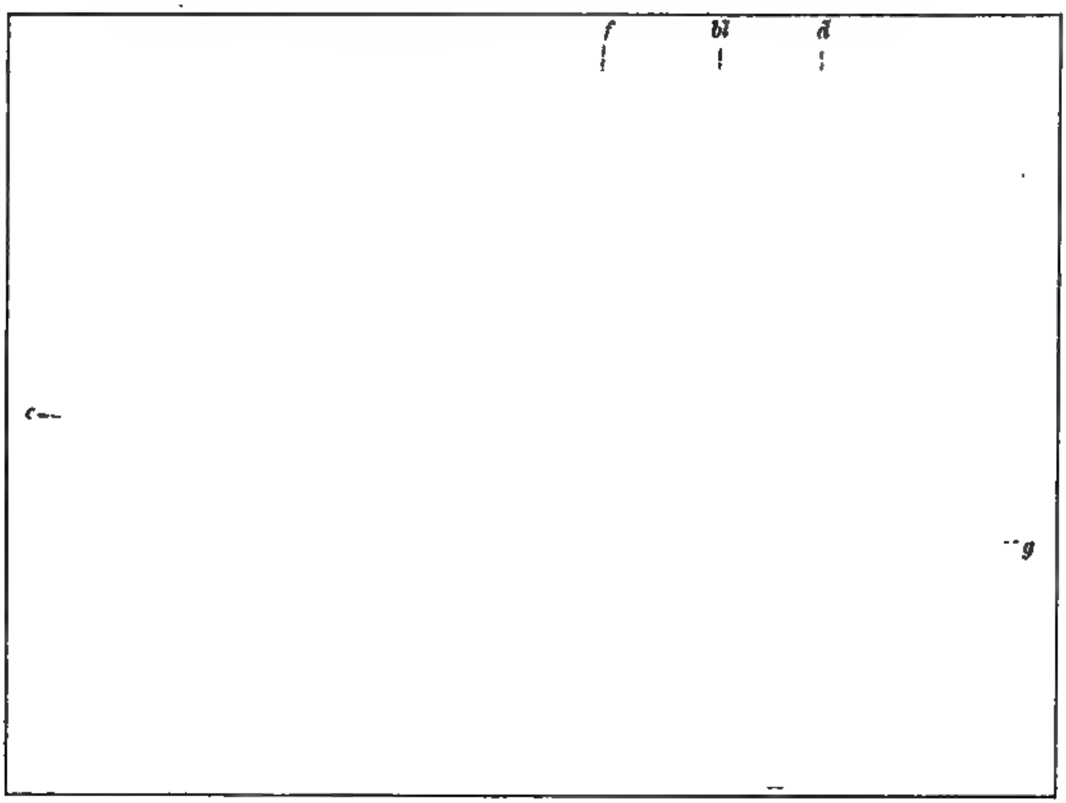

Fig. 208. Leaf cutting from a hybrid form of Begonia Rex.

the various authors are often explained by the fact that individuals of the same plant species under different conditions and of different age do not always show exactly the same processes. Beinling's[1] investigations, for example, prove that the genus Peperomia does not form any callus but covers the cut surface with wound cork. He also found buds produced from the ground parenchyma of the petiole, or the blade, but not from the epidermis and always independent of the vascular bundle. On the other

[1] Beinling, E., Untersuchungen über die Entstehung der adventiven Wurzeln und Laubknospen an Blattstecklingen von Peperomia. Inauguraldissertation. Breslau 1878, p. 23.

hand, Hansen[1] describes in detail the processes of root and sprout formation in Achimenes and Peperomia from the callus. In this only the first adventitious roots are produced from the already existing tissue elements. After the callus tissue had increased for some time numerous pro-cambial strands showed themselves in the callus, extending in all directions toward the surface. Their cells soon changed into tracheae; so that "callus"[2] is provided with a branched system of vascular bundles. Soon the peripheral cells of this tissue appear to be abundantly filled with protoplasm; they divide and produce a meristem which differentiates, as do the normal vegetative points, and soon an epidermis becomes very distinct.

In the leaf cuttings of the monocotyledons, the processes of bud formation are the same as those in dicotyledons. Magnus[3] describes bulb cuttings of hyacinths. Numerous adventitious buds are formed on the ventral side of the cut surface which, in case the bulb scale was still young, are produced from an epidermal cell or in older scale pieces from the underlying parenchyma. At first tender knobs of tissue are formed from the dividing tissue cells which continue growth at the apex in diverging cell rows; dividing dichotomously. It is, therefore, actual callus. On further developed knobs, a circular wall appears, developing into the first sheath-like scale of the adventitious bud, while the enclosed apical cell shows growth in diverging cell rows. On the bulb scales of *Lilium Tigrinum* and *L. Auratum* the buds are also formed on the outer edge of the inner side. The rootlets, arising on the outer side from the phloem region of the vascular bundles, live only a short time since the young plant at once forms independent roots.

The processes of bud formation in leaf cuttings do not differ essentially from the voluntary production of the buds on uninjured leaves on the plant. Numerous examples of these are well known[4]. They have been observed in mosses and ferns[5], in lilies and other monocotyledons, most numerously in dicotyledons. Beijerinck formed as a law for the latter, that the vascular bundles of the leaf have an influence on the primordia of the adventitious

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1 Hansen, Ad., Über Adventivbildungen. Sitzungsber. d. phys.-med. Soc. zu Erlangen vom 14 Juni, 1880; cit. Bot. Centralbl. 1880, p. 1001.

2 Opportunity is here given to call attention to the fact that the authors include two different conditions under the name "Callus."

They call tissue callus which is produced from the first cell divisions, and has for some time an arrangement in rows; it continues growth, especially at the apex of the cell rows, and lacks all differentiation.

In the second place, however, the authors, in accordance with general usage, understand by callus the structure differentiated from the callus by the production of a cork zone, the formation of an inner meristem centre and the separation of a ground tissue. This structure has already become similar to the tissue from the wound in which it is produced. However, the juvenile conditions, distinguished by apical growth, should be distinguished from these mature conditions and I propose, on this account, to apply the term "callus" only to the first structures, while the later stages can be known as "cicatrization tissue."

3 Magnus, Hyacinthenblätter als Stecklinge. Sitzungsber. d. Ges. naturforsch. Freunde vom 16 Juli, 1878; cit. Bot. Zeit. 1878, p. 765.

4 Beijerinck, M. W., Over het onstaan van Knoppen en wortels uit bladen. Nederl. Kruidkund. Archief. Serie II, Deel III, p. 438-493; cit. Bot. Centralbl. 1883, No. 17, p. 112.

5 Farlow, Bot. Zeit. 1874, p. 180.—Cramer, Geschlechtslose Vermehrung des Farnprothalliums, namentlich durch Gemmen resp. Konidien. Denkschr. d. Schweiz. Naturforsch. Ges. XXVIII, 1880.

organs. The adventitious buds are always found on the upper surface where the woody part of the vascular bundles is turned toward the upper side of the leaf; they are produced in the axes of the ribs and are usually more strongly developed the thicker the vascular bundles. The roots are produced from the phloem side of the vascular bundles.

Regel[1] enumerates the plants on which buds of leaf origin have been observed. A few examples may be named here since the buds develop their own roots after having been carefully removed from the leaf and, therefore, are of importance in propagation. Besides the well known *Bryophyllum calycinum,* which Berge[2] studied and on which incisions between two serrations of the leaf develop a meristematic tissue in an early stage and from this meristem buds, the following species are noteworthy: *Hyacinthus Pauzolsii, Fritillaria imperialis, Ornithogalum thyrsodies,* Drimia, Malaxis, Cardamine, Nasturtium, *Brassica oleracea, Ranunculus bulbosus, Chelidonium majus, Levisticum offic.,* Ultricularia, *Begonia quadri-color, B. phyllomaniaca*[3]. Hansen[4] mentions also Hippuris, *Elodea canadensis* and other water marsh plants. Caspary[5] mentions *Nymphaea micrantha* and its hybrids. He also cites examples in which an inflorescence developed instead of a leaf. In this way the upper side of the petiole of a cucumber (*Cucumis sativus*) was covered with more than 120 staminate blossoms without a single vegetable leaf.

The success of propagation by leaf cuttings depends upon the individuality of the leaf as well as upon the plant species. Very young leaves must be excluded because of the immaturity of their tissue systems; very old ones because of their scanty life energy and the ripeness of their chlorophyll apparatus.

According to Lindemuth's[6] observations, in genera where the leaves can be used as cuttings, the plants thus produced are on an average stronger than those from wood cuttings. As soon as a leaf has developed a few roots, it may be considered a new individual, even when it is not able to produce shoots. This arises from the capacity of such leaves to live longer than unrooted ones and Goebel[7] could also prove an increased growth in thickness (in Bryophyllum). Lindemuth also observed, in a begonia, that a flower shoot can be formed instead of foliage shoots in leaf cuttings. This circumstance might indicate that the leaves *furnish different products of assimilation at different ages and places on the axis.* Usually the assimilates capacitate the bud, produced on the leaf cutting, to form only foliage shoots.

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[1] Loc. cit., p. 452.
[2] Beiträge zur Entwicklungsgeschichte von **Bryophyllum calycinum.** Zürich 1877; cit. Bot. Jahresber. IV, p. 423.
[3] Mohl, Über die Cambiumschicht des Stammes der Phanerogamen und ihr Verhältnis zum Dickenwachstum desselben. Bot. Zeit. 1858, p. 196.
[4] Loc. cit., p. 1002.
[5] Caspary, Blütensprosse auf Blättern. Schriften d. phys.-ökonom. Gesellsch. XV, 1874, p. 99.
[6] Lindemuth, H., Weitere Mitteilungen über regenerative Wurzel- und Sprossbildung auf Laubblättern (Blattstecklinge). Gartenflora 1903, p. 619.
[7] Flora 1903, p. 133.

Often, however, they are of a concentration which makes possible the formation of flower buds.

In general practice at times the petiole is used for propagation instead of the leaf, in case the leaf itself is too tender. A recent example is the propagation of the cultivated forms of *Begonia semperflorens*, which is sold under the name of *Gloire de Lorraine* and greatly prized as a winter bloomer[1]. In February the most vigorous leaves are cut off close to the stem and the petiole set 1 to 2 cm. deep in sand and peat mold. At a temperature of 18 to 22 degrees C. these petioles form root balls as large as walnuts. Other begonias as, for example, the Rex forms set roots from their petioles but almost never develop strong buds. The petioles of cabbage, celery and other fleshy plants behave similarly.

The flower stems of *Primula sinensis* may be used successfully as cuttings. Cramer[2] used flowers with the leaf-like perianth of this plant, in which buds were produced in the axes of the reproductive leaves. A case, which Baillon observed, showed that the fruit could also be used as cuttings; in this, roots developed from the fruit of a cactus[3]. The same author also cut in two just above the base the ovary of *Jussieus salicifolia.* This bore two leaflets near the centre, and was cut during and after blossoming in such a way that the ovules could be seen; these cuttings were set in a pot. Three weeks later the well-rooted cuttings were transplanted. A small branch with scales appeared in the angle of the carpels. The upper part of the blossom died and a circular scar was formed[4]. Irmisch describes root formation on the cotyledons of *Bunium creticum* and *Carum Bulbocastanum*[5]. I have seen root formation in the broken-off cotyledons of beans (*Phaseolus vulgaris*). Carrière found roots on the fruits of *Lilium lancifolium.* Beinling[6] found flower stems of Echeveria which, in moist sand, had grown roots.

Hildebrand[7] describes a fruit of *Opuntia Ficus indica* out of which a second had sprouted; both fruits after separation from the plant developed leaf sprouts. The same thing happened with blossom buds of *Opuntia Raffinesquiana.* Therefore, each plant organ may be capable of developing leaf sprouts by the formation of adventitious buds, provided first that it contains enough reserve substances to live for some time separated from the parent plant, and secondly that the external conditions are favorable. A summary by Magnus[8] gives further details together with the theories of Klebs, Goebel and others.

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1 Kirst, Vermehrung der Begonie "Gloire de Lorraine." Prakt. Ratgeber im Obst- u. Gartenbau 1906, No. 5.

2 Bildungsabweichungen, p. 37.

3 Vegetable Teratologie, p. 160.

4 Bot. Zeit. 1865, p. 527, from Adansonia, Vol. I, p. 181.

5 Flora 1858, p. 32, 42.

6 Beinling, Untersuchungen über die Entstehung der adventiven Wurzeln und Laubknospen an Blattstecklingen von Peperomia. Inaug.-Diss. Breslau 1878.

7 Hildebrand, F., Über Bildung von Laubsprossen aus Blütensprossen von Opuntia. Ber. d. Deutsch. Bot. Ges. 1888, Vol. VI, p. 109.

8 Magnus, Werner, Regenerationserscheinungen bei Pflanzen. Naturwissensch. Wochenschrift 1906, No. 40.

INJURY TO THE FOLIAGE.

The results of partial or entire *defoliation* must naturally become apparent in the amount of dry substance produced. The effect varies according to the amount and age of the leaves removed and also the possibility of compensation for the lack of foliage by the existing buds and the amount of reserve substances necessary for their unfolding stored in the axis.

The annual reports on forestry give sufficient examples for forest trees. It is not necessary to go further into this subject here since each separate case must be judged for itself. In the numerous injuries due to caterpillars, for example, the amount of injury depends upon the time and duration of the eating. Reference should be made, in this connection, to Ratzeburg[1]. He describes, in detail, the influence of defoliation on the annual ring formation of spruces and pines and treats later of deciduous trees[2]. Cieslar's[3] experiments show that the anatomical structure of a wood ring, produced after extensive defoliation, was changed (it became much more tender). Under certain circumstances the vessels can be entirely lacking[4] in wood produced after defoliation. Hartig[5] had already proved that a decrease in number of the vessels goes hand in hand with the decrease of foliage. Kny[6] had already touched on the subject that under certain circumstances double annual rings can be produced. Wieler[7] showed by experiments that the boundaries between spring and summer wood can be entirely effaced by changes in nourishment.

Such effects can also occur in fruit trees and often manifest themselves in the yield. In only a few cases can a partial defoliation prove to be advisable agriculturally as, for example, in grapevines, if they constantly produce new foliage shoots which use up the supply of nutrition necessary for the maturing of the grapes.

Among annual and biennial cultivated plants, beets come especially under consideration because, in years when fodder is scarce, the older leaves are broken off in the course of the summer and used to feed the cattle. An example from Bohemia[8] proves that the root body is thereby forced to form more new foliage than it would otherwise and that the storage of reserve substances suffers from this. It was found here that, after defoliation, not only did the beet root remain smaller but the sugar content was about 10

1 Ratzeburg, Waldverderbnis, I, p. 160, 234, etc.
2 Loc. cit. II, p. 154, 190, 233.
3 Cieslar, A., Über den Einfluss verschiedenartiger Entnadelung auf Grösse und Form des Zuwachses der Schwarzföhre. Cit. Just's Jahresber. 1900, II, p. 278.
4 Lutz, K. G., Beiträge zur Physiologie der Holzgewächse. Ber. D. Bot. Ges. 1895, p. 185.
5 Hartig, R., Über Dickenwachstum und Jahrringbildung. Cit. Zeitschr. f. Pflanzenkr. 1892, p. 292.
6 Verhandl. d. Bot. V. d. Prov. Brandenburg 1879.
7 Wieler, A., Über Beziehungen zwischen dem sekundären Dickenwachstum und den Ernährungsverhältnissen der Bäume. Tharander forstl. Jahrb. 1892, V. 42.
8 Blätter f. Zuckerrübenbau. 1905, No. 20.

per cent. less than in the undisturbed beets. Aderhold's[1] experiments with roots and grain gave similar results. It was found in grain that the length of the heads was strongly affected, irrespective of the reduction of the whole harvest.

Nevertheless, one's fears should not carry one too far, nor should slight losses of leaf substances be considered of too great importance as has recently been estimated by many pathologists in judging the injury due to fungi. It must not be forgotten that the parts of still vigorously growing leaves, which have lost some of their lamina, are excited to increased effort, as I have proved experimentally[2]. Boirivant[3] found, in fact, that after the removal of leaf blades the petioles and stems participate to a greater degree than usual in the assimilation and that their parenchymatous tissue can begin to elongate and increase.

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1 Aderhold, R., Über die durch teilweise Zerstörung des Blattwerkes der Pflanze zugefügten Schäden. Prakt. Blätter f. Pflanzenbau u. Pflanzenschutz. III Jahrg. 1905, Part 2.

2 Sorauer, P. Studien über Verdunstung. Forsch. a. d. Gebiete der Agrikulturphysik. Vol. III, Part 4-5, p. 109.

3 Boirivant, A., Sur les tissu assimilateur des tiges privées de feuilles. Just's Bot. Jahresb. 1898, II, p. 231.

SUPPLEMENT.

Page 307. New investigations on *Chlorosis* have been published by Molz (Die Chlorose der Reben, Jena 1907, G. Fischer). In confirmation of the theory, which we have expressed, a lack of oxygen for the roots may actually be considered as the cause. On this account low positions, where water flowing from higher ground can collect, are the most dangerous. In heavy soils the development of the root system suffers from this. Lime itself cannot produce chlorosis but soils rich in lime cause especially the death of the roots, since they are often very fine grained and can produce an alkaline reaction. Therefore, we may speak of a *calcium chlorosis*. Continued drought, as well as cold, can also produce chlorosis. Worth consideration is Molz's theory that the weak constitution of a chlorotic plant can be carried over by the wood used for propagation. The disease can either be inherent in the cuttings from the beginning, or "certain disadvantageous circumstances from outside, resulting from an inherited, strong predisposition, can cause the production of the icteric phenomenon and its results." A permanent cure cannot be brought about by *iron sulfate*. At best only the symptoms will be removed and it is probable that the greening of the leaves is not caused by the iron but by the *sulfuric acid*.

Page 335. Molz studied *dropsy in grape cuttings* (Bericht der Kgl. Lehranstalt zu Geisenheim a. Rhein, 1906). The cuttings had stood for some time in damp soil. They were swollen up like clubs in different places, thus splitting lengthwise the outermost tissue layers. A white, spongy tissue became visible in the gaping wound, which consisted of hypertrophied bark cells. Molz considers the disease, which is not uncommon in moist vineyards, to be identical with that in *Ribes aureum* described by Sorauer.

Page 345. Black specks are found in the one-year-old shoots of *Vitis vinifera* and appear somewhat raised. Molz (Centralblatt f. Bakt. II, Vol. XX, 1908, Nos. 8 und 9) describes these as small, round knobs of a blunt, conical form ("bark warts"), which may be considered as a compensation for the lenticles not found in *Vitis vinifera*. Each one has a stoma on its tip which dries up rather early. This drying extends to the neighboring cell groups and advances until halted by the formation of a protecting cork layer. The stronger and better nourished the tissue is the more quickly the

protecting cork is produced. Poorly nourished shoots produce no protecting cork and on this account bear especially large and numerous bark warts. These black specks, therefore, furnish a standard for judging the degree of maturity of the wood and the health of the vine. The more numerous and the larger they are, the less mature in general is the wood.

Page 378. In Geisenheim, Julie Jäger observed a wen formation of the apple tree (Zeitschr. f. Pflanzenkrankh. 1908). The cause has not been sufficiently determined, but is probably to be found in some disturbance of nutrition, which manifests itself in the widening of the medullary rays. Some medullary rays in their primordia show a greater cell increase and widening of the individual cells. The process is connected with the formation of gnarl spikes from the medullary excrescences in *Ribes nigrum* and *Pirus malus chinensis,* which we have described.

Pages 391 and 395. *The iron spotted condition of potatoes* was unusually wide-spread in the wet year of 1907 and connected with it appeared a yellow to brown discoloration in the vascular bundle ring. This discoloration, in common with a frequent diseasing of the stem end, in which at times a Fusarium was concerned, has influenced Appel to explain the so-called leaf roll disease, a form of the curling disease, as a fungus epidemic. Appel maintains that the Fusarium, found at the stem end, grew during the winter through the vascular bundle ring into the eyes of the tuber and caused the following year an increased occurrence of the disease and a gradual destruction of the potatoes. The same theory has been advanced by Reinke and Hallier, only they have made another fungus responsible for it. Sorauer proves (Internationaler phytopathol. Dienst, Stück 2, 1908) that the Fusarium, to be sure, may be found frequently but that other slime fungi appear just as often; that all fungi could never be observed to be growing in the vascular bundle ring of the tuber up to the eyes. It is not a question of a fungous disease and its continuance through the tubers into the following year. The phenomena of discoloration in the tuber may rather be explained by the increase of the enzymes which Prof. Grüss has proved to have accumulated especially about the stem end. Consequently, a relatively larger amount of sugar would be present, which would form an especially favorable substratum for numerous microorganisms.

Page 496. The influence of electricity on plant growth was tested at the Hatch Experiment Station of the Massachusetts Agricultural College (cit. Z. f. Pflanzenkrankh. 1908). *Raphanus sativus* was used as the experimental plant. It showed a hastening of the rate of growth and an increase in weight of foliage and roots; the leaves, however, were a lighter green and were inclined to leaf blight. The electric stimulus seems to act on the organs in the same way as does a lack of light.

Gassner (Berichte d. D. Bot. Ges., 1907, Part 1) can confirm the results of Löwenherz's experiments mentioned in the text. The curvature produced

by the action of the current, which could be observed in all plants, did not always remain the same. At times it was toward the negative pole; in other cases, toward the positive pole.

In opposition to the cultural experiments with barley, published earlier by Löwenherz and confirmed later by Gassner, which prove an injurious effect of the electric current, the first named author now reports favorable results (Z. f. Pflanzenkrankh. 1908, Part 1). With a weaker current he found a hastening of the growth of a seedling; the injurious action began only with an increase of the current.

Page 524. In the reports of the Hatch Experiment Station of the Massachusetts Agricultural College (cit. Z. f. Pflanzenkrankh. 1908) may be found observations on the *leaf blight of conifers* and other evergreen trees as the result of winter and spring frosts. The trees show the blight usually only on one side, which corresponds to the prevailing direction of the wind. If dry winds blow with a high temperature at a time when the soil is still frozen, the plants cannot find sufficient compensation in the frozen soil for the increased transpiration and the leaves dry up. This is the same theory which found expression earlier as explanation for the dropping of pine needles. The native conifers suffered less, in case they did not stand on unfavorable soil, when compared with the imported varieties of Picea, Abies, Juniperus, Taxus, Buxus, etc.

Page 675. According to Stocklasa's investigations, Ueber die *glykolytischen Enzyme in Pflanzenorganismus,* Z. f. physiol. Chemie, Vols. 50 and 51, 1907, the anaërobic respiration is an alcoholic fermentation in which a certain amount of lactic acid has formed together with alcohol and carbon dioxid. This holds good also for frozen organs (beets, potatoes, etc.). Zymases and lactacidases are, therefore, not destroyed by the freezing. Lactic acid, alcohol, carbon dioxid, acetic and formic acid are also formed by enzymes in living plant and animal cells. The decomposition of the hexoses by glycolytic enzymes is normally completed without the coöperation of bacteria. In the precipitates procured from pure plant juices by absolute alcohol and ether, the author found fermentation enzymes which produced a lactic acid and alcohol fermentation in the glycose solution; in this process with easy access of oxygen definite amounts of acetic and formic acid are always formed.

Page 677. Fallada's investigations (Oesterr. Ungar. Zeitschr. f. Zucherindustrie u. Landw. Part V, 1907) on the *white leaf conditions of beets* favor the theory that the white parts of the leaf remain in a younger developmental stage and with a scantier cell content and are more susceptible to the influence of light and heat than are the green organs. The etiolated leaves had a greater water content; the smaller amount of organic substances gave a relative increase of protein especially of the non-albuminous nitrogen compounds. The potassium and phosphoric content was greater; the calcium and silicic acid content was smaller.

Page 717. For the diseases of the horseradish, we have referred to our detailed article in the Zeitschrift für Pflanzenkrankheiten, 1899, p. 132. It is stated there, "The forms of disease mentioned appear to me on this account only as a great increase of a wide-spread tendency to gummy degeneration . . . because in the production of the masses filling the vessels the liquification of the secondary membranes coöperates in certain cases." This theory has been shared recently by A. Schleyer (Der Anbau des Merrettichs usw. cit. Biedermanns Zentralbl. f. Agrik., Part 8, 1908). He says, "In my opinion, the turning black is conditioned by the fact that the Pentosane and the sugar in the horseradish degenerates into gum." Experiments also confirm the theory that lime should be used as a remedy (since humic acid is often present in the soil). When the plants were cultivated in nutrient solutions, some of which were made up with calcium, others without it, the gummy degeneration of "the sugar" could be proved very soon in the plants which did not have calcium.

Page 718. The subject of the injuries due to the *gases of smoke* and other industrial waste substances is beginning to be separated as a special branch of general pathology and is represented by a special publication. Since 1908, there has existed the "Sammlung von Abhandlungen über Abgase und Rauchschäden" edited by Prof. Dr. Wislicenus, who has already given in the first part a comprehensive description "Ueber die Grundlagen technischer und gesetzlicher Massnahmen gegen Rauchschäden."

Recent investigations by Haselhoff (Z. f. Pflanzenkrankh. 1908) treat of the action of sulfurous acid on soil. The experiments show that vegetation is not injured if the soil contains such amounts of decomposable bases (especially calcium) that the sulfuric acid, formed from the supplied acid, is combined. The case described by Wieler of soil impoverishment in the presence of free acids in the soil may be found very rarely (perhaps in forest soils). If, on the other hand, sulfurous acid is introduced into the soil during the growth of the plants so that it shows an acid condition, disturbances in growth become clearly noticeable. In *soils containing copper,* the copper is carried over into easily soluble compounds of the sulfurous acid and this dissolved copper can then become injurious to vegetation. But even here calcium carbonate helps since it arrests the dissolving action of the acid.

Page 761. The occurrence of a disadvantageous effect of Bordeaux solution on the yield, which we first observed, has been confirmed by recent experiments of v. Kirchner (Z. f. Pflankrank., Part II, 1908). The author takes the older literature also into consideration. Probably the shading action of the solution should be made responsible for the lessened yield. This would explain also the rapid turning green of leaves with strong illumination. The greater amount of starch is not to be ascribed to increased assimilation but to a decreased removal of the assimilates.

Page 765. Kelhofer (Internat. phytopath. Dinest, 1908, Part 3) has reported some points in regard to the making of *Bordeaux Mixture.* The effectiveness of the mixture depends not only on the quality of the materials used but also on the proportionate amounts of the two elements and on the method of preparation.

In regard to the proportionate amounts, it should be emphasized that the copper precipitate loses its physical properties the more quickly and the danger of washing away by rain is the greater the more calcium is used in preparing the solution. According to Kelhofer's experiments, it is further desirable that the copper vitriol solution and the lime milk are mixed when cool and in the most dilute condition possible and, on this account, the copper solution must be poured slowly into the lime milk; otherwise the precipitate assumes a powdery form which conglobates. Although the addition of sugar is to be recommended in general, care must be taken not to use too large amounts since the copper solution thereby may be more easily washed away. At any rate the amount of sugar necessary to make the mixture keep depends upon the amount of calcium, inasmuch as solutions prepared with a good deal of calcium need more sugar. Thus, for example, when using 1, 2 and 3 kg. calcium, to 2 kg. vitriol to each 100 liters of water, 20, 30 or 40 gr. of sugar have been found necessary in order to protect the copper precipitate permanently from decomposition, i. e. for at least a year. In common usage, where, as a rule, plenty of calcium is used, it is advisable to take on an average 50 gr. sugar for each hektoliter. With this addition the whole amount of Bordeaux mixture needed can be prepared at the same time in the spring at the beginning of the season; the mixture will then keep through the summer.

Page 772. The investigations of Rudolph Friedrich (Ueber die Stoffwechselvorgänge der Verletzung von Pflanzen. Centralbl. f. Bakteriologie, etc. II, Vol. XXI, p. 330) have confirmed the observations of Zaleski and Hettinger that an increase of protein takes place at the *wounded place.* Besides this, however, Friedrich found that in the storage organs beneath the soil, as well as in the fruits and leaves, a decrease of carbo-hydrates and an increase of acidity (with the exception of bulbs) sets in as a common, secondary phenomenon of the injury. If, with Ad. Mayer, the acids are considered as the products of oxidation of the sugars, then the increased acidity is explained by the more active respiratory need of the injured organ. The decrease of carbo-hydrates will be explained partially by the fact that they are used for protein synthesis. A corresponding decrease of amids or the amido acids may be considered as further reactions to *traumatic stimulus.* These substances are used in the construction of the protein molecule. In the potato the smallest starch grains are used up and introduce the formation of sugar.

Page 787. Hedrick, Taylor and Wellington made *girdling experiments* on tomatoes and chrysanthemums (Bulletin 288 of the Agriculture

Experiment Station at Geneva). No beneficial effects could be determined. On the contrary, the plants were very evidently injured. Knobby swellings were formed on the axes; the leaves became sickly and the root system less developed.

A confirmation of my personal studies on the processes after girdling may be found in Krieg's contributions on callus and wound wood formation in girdled branches and their histological changes (Beiträge zur Kallus- und Wundholzbildung geringelter Zweige und deren histologische Veränderungen. Würzburg 1908, Nubers Verl.). The observations on Vitis are new in that the formation of new structures as a result of girdling were proved in the pith, although the pith had not been injured at all. This fact is important because it shows that the *wound stimulus,* or the changes in tissue tension setting in after each injury, manifests itself in regions far distant from the wound surface and separated from it by firm wood zones. This makes better understandable the changes in the pith body due to frost injuries in which the wood ring shows no disturbances of any kind.

The formation of wound wood in the pith of Vitis was observed by Krieg, who ascribes it to the action of the products of decomposition of the woody part killed by the girdling. This wound wood consisted of parenchymatous aggregations resembling pith spots. These were enclosed by a ring of cambium. The ring lying within the pith bark developed wood with numerous vessels toward the inside and sieve tubes toward the outside. The other pith spot, adjacent to the pith crown, formed the sieve tubes from its cambial ring toward the inside and wood toward the outside. The corresponding parts of both new structures united later with the respective parts of the overgrowth edge. In the meantime, the plant had replaced the wood already killed in girdling by the formation of new wood and sieve tissue in the pith.

Page 825. We owe varied and careful experiments to Elsie Kupfer (Studies in Plant Regeneration. Dissertation of Columbia University, New York, 1907). Of these, we will emphasize first the experiments on *root cuttings* of *Roripa Armoracia.* Pieces of the root laid flat in the soil formed new shoots from the cambium of both the upper and under cut surfaces. If bark and cambium had been cut away, sprouts developed after a preliminary callus formation at different places near the vascular bundle and more abundantly at the upper than on the under end. The capacity to form sprouts, which otherwise is peculiar to the cambium, therefore, extends in this case to the callus tissue newly produced as a reaction to wound stimulus. Longitudinal sections of roots of *Pastinaca sativa,* which were laid horizontal in sand, developed new sprouts on both cut surfaces near the cambium. In isolated pieces of bark, sprouts were produced on the inner side and roots on the outer side. The isolated central cylinder formed only roots.

The experiments with potatoes are very instructive. If any eye at all was left uninjured on some aërial shoot, this developed an aërial tuber. If

all the eyes were removed, only root formation took place. Pieces of potato tubers, from which the eyes had been cut out together with the adjoining tuber parenchyma, formed new eyes on these cut surfaces. In the potato leaves, either a simple formation of roots appears at the under end of the petiole or a tuber swelling, containing starch, or a combination of the two, or a regular small tuber with eyes.

As a total result of all the experiments for which blossom and fruit stems were also used with success, we may recognize that for *regeneration* the presence of an abundant reserve material is necessary. Pure white sprouts of different plants formed no roots. Darkening, or removal of the carbon dioxid, prevented regeneration. Since certain parts of the plant are not capable of regenerating one or another organ, even when all conditions are favorable, one is led to the point of view that different substances must be present which determine the formation of any certain organ. Such substances should be thought of in the form of *enzymes*, which are not present in all cells but are localized in definite parts of the plant body.

Page 833. In regard to callus formation, which takes place between the bark shield and stock, Ohlmann expresses himself in his detailed work (Ueber die Art und das Zustandekommen der Verwachsung zweier *Pfropfsymbionten*. Centralbl. f. Bakteriol. usw. II, Vol. XXI 1908) as follows: "It seems, therefore, that callus formation may begin only at the bark shield. Sorauer states in regard to this question that no law for the tearing away of the bark may be determined. According to Schmitthenner, the trunk splits in the youngest sapwood. I have investigated a great number of plants of widely different species in regard to this question. It was evident that the cambium remained intact on the bark. In more scattered cases, I noticed that a few cambial cells had remained hanging to the youngest wood. Nevertheless, I have noticed this so rarely that I cannot ascribe any significance to it." It should be remarked here that the author did the budding at a time "when the cambial activity was in full progress." In this case, the author was correct. If the budding is done later, however, then the cases observed by Sorauer become more numerous.

Page 854. Blankinship describes a *bleeding disease* occurring frequently in Montana (North America) in *Populus augustifolia, P. balsamifera, P. deltoides,* etc. (Zeitschr. f. Pflanzenkh., Part 1, 1908). The trees bled extremely from wounds and this was accompanied by the bleaching or yellowing of the foliage. At times the wounds on different axes developed into cavities filled with a gummy, half fluid mass. The exuding sap, laden with bacteria, had a sweetish taste and had often attracted large brown ants.

A *"Jaundice"* of the poplar is connected with this bleeding disease, in which bleeding may also appear but more frequently does not. The foliage of the whole tree is bleached and dries up in the intercostal fields. Death

follows after 3 to 5 years. The diseased trees stand generally in low places and the author is of the opinion that the increase of the alkali content in the ground water is to blame. This trouble is found in Montana not simply on poplars but also on other trees where irrigation is used. Drainage is advisable.

Pagė 856. Minora Shiga (On the effect of a partial removal of roots and leaves upon the development of flowers. Journ. College of Science, Tokyo, 1907, Vol. XXIII, Art. 4), reports on the *promotion of blossom development* by the removal of the part of the roots. Different species of very different plants experimented on acted differently under the same manipulation. In Pharbitis, *Pisum arvense* and *Vicia Faba* the removal of the main root and small lateral roots cause an unusually early and luxuriant development of the blossoms. This was not the case in Fagopyrum. Cutting off of the side roots promoted the formation of blossoms in *Vicia Faba* and *Pisum sativum* var. *arvense,* but did not dô so in *Pisum Arvense.*

End of Vol. I.

INDEX TO VOLUME I.*

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